2020 - Book Chapter AR Front cover + Content.pdf

by

Chapter 9

The Development of Augmented Reality Applications for Chemistry Learning

Ferli Septi Irwansyah, Efa Nur Asyiah, Dian Sa'adillah Maylawati, Ida Farida, and Muhammad Ali Ramdhani

Abstract This chapter describes the use of Augmented Reality (AR) technology in chemistry education. The chapter begins with definition analysis, development, component, working principles, steps in making AR media, and supporting applications that are related with AR in education particularly for chemistry teaching and learning process. The proposed AR system consists of three parts: computers, Head Mounted Display (HMD), and markers that use AR toolkit working principles as follows: making AR through Vuforia setting stage, making the target management, managing assets, and running processes. Additionally, Unity application also supports in AR making. There were researches in the field of education especially in chemistry teaching and learning that had used AR technology, such as the concept of crystal structure, molecular geometry, molecular chirality, and molecular hybridization.

9.1 Introduction

Since 1957, Augmented Reality (AR) has existed as one of the contributors to technological advances that can combine the real world with the virtual world (Isberto 2018). Until now, AR has played many roles in all fields, such as health, medicine, agriculture, and education (Martin et al. 2018).

F. S. Irwansyah (✉) · E. Nur Asyiah · I. Farida
Department of Chemistry Education, UIN Sunan Gunung Djati, Bandung, Indonesia
e-mail: ferli@uinsgd.ac.id

E. Nur Asyiah
e-mail: nurasyiahefa@gmail.com

I. Farida
e-mail: farchemia65@uinsgd.ac.id

D. S. Maylawati · M. A. Ramdhani
Department of Informatics, UIN Sunan Gunung Djati, Bandung, Indonesia
e-mail: diansm@uinsgd.ac.id

M. A. Ramdhani
e-mail: m_ali_ramdhani@uinsgd.ac.id

V. Geroimenko (ed.), *Augmented Reality in Education*,
Springer Series on Cultural Computing,
https://doi.org/10.1007/978-3-030-42156-4_9

AR is very useful in education, along with students' understanding of invisible concepts (Smith and Nakhleh 2011). In Augmented Reality (AR), education is positioned as a learning. The use of instructional media by utilizing Augmented Reality can stimulate students to think critically about problems and events that occur in their daily life since it helps students to learn autonomously (Oh and Byun 2012). Moreover, AR is used in a smartphone which most of the students are familiar with (Zan 2015). Augmented Reality media can illustrate abstract concepts to understand and arrange objects, enabling AR to become better media in accordance with the objectives of learning media (Oh and Byun 2012).

Using Augmented Reality media is very useful to improve student learning outcomes and interests (Carmigniani et al. 2011). In terms of effectiveness, many students support that the Augmented Reality media in the Android version by using smartphones in natural science lessons can help them understand and memorize scientific material so that they easily understand science lessons (Zan 2015). It also helps them to learn in their own way and increase their creativity and imagination since Augmented Reality can increase student concentration (Han 2018). Some researches in the field of education particularly chemistry education that has been carried out using AR were based on the concept of crystal structure (Irwansyah et al. 2017), molecular geometry (Irwansyah et al. 2018), molecular chirality (Jannah et al. 2019), molecular hybridization (Asyiah et al. 2019), and alkanes and cycloalkanes.

It is expected that Augmented Reality (AR) in chemistry teaching and learning will be continually developed in other submicroscopic concepts and hopefully the improvement media could be more optimal in system without markers so that it can be used easier without scanning.

9.2 Development of Augmented Reality Technology as a Learning Media on Metal Structure Concepts

Augmented Reality as a learning media on metal structure material consists of several concepts: solid structure, seven basic crystal systems, and metal structures. This study refers to the modified Computer Assisted Instruction (CAI) tutorial model design (Darmawan 2012), which consists of the analysis phase, the design development stage, and the validation stage.

Making of instructional media needs to be adapted to the material (Arsyad 2007) of metal structures, so that concept analysis and concept maps of metal structures with the connectedness of submicroscopic representations were made. This is supported by the results of the due diligence test which are declared valid and suitable for use in the aspect of material substance (Irwansyah et al. 2017).

AR on metal structure material sub microscopically represents 3D objects presented by the marker. This learning media has advantages in terms of appearance that is offered inductively to stimulate curiosity, develop students' thinking skills (Arsyad 2007), and increase motivation (Irwansyah et al. 2017) and can be adjusted to the applicable curriculum. This is evidenced by the feasibility test on the aspect of visual communication which is declared valid and quite feasible to use (Irwansyah et al. 2017).

The process of making AR learning media in metal structure material must refer to the outline to assist in creating AR media. Based on the results of concept analysis, a flowchart is produced as a reference and a storyboard as a designed outline (Darmawan 2012).

9.2.1 Start Display

The sign in view contains a camera view that will display 3D objects of metal structure when it is projected with a marker. 3D objects shown include (1) structural objects of crystalline and amorphous solids, (2) structural objects of seven basic crystal systems, (3) tightly packed packaging structures of metal, and (4) metal structures.

This learning media is assisted by smartphones and student worksheets, which direct users to develop submicroscopic representation capabilities in metal structure material. Worksheets direct students to work on questions that have been made according to indicators. The use of smartphone makes learning media effective and efficient. The process showed that it was feasible and valid. However, the function of the media must be adjusted again in the delivery of material to avoid verbalism (Sadiman 2009). Visualization of objects in the worksheet is shown in Fig. 9.1.

9.2.2 Display Learning Objectives

Display learning objectives contain learning objectives on metal structure material that must be achieved by students, namely, the ability to analyze the structure of solid substances and seven basic crystal systems based on the three-dimensional parameters of the space lattice, determine the tight packing structure of a metal. The learning objectives are arranged based on the development of students' submicroscopic representation capabilities on metal structure material and adapted to the learning media (Sadiman 2009). The purpose of this learning is to get a decent response from respondents (Irwansyah et al. 2017), which results in the media that is ready to be used as a source of learning (Sudjana 2009).

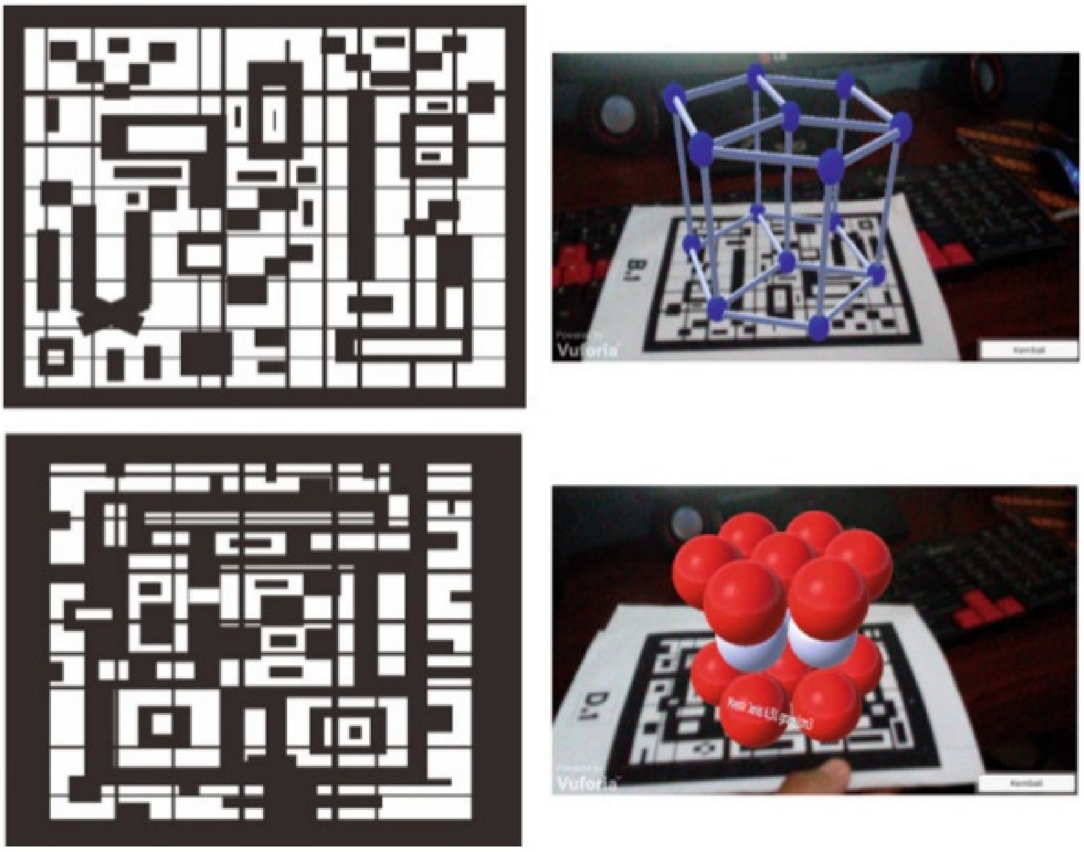


Fig. 9.1 3D object visualization

9.3 AR Technology Using Android Operating System on the Concept of Molecular Geometry

This study refers to a CAI-based tutorial (Computer Assisted Instruction) (Molenda and Januszewski 2008). AR media is made on the concept of molecular geometry through the analysis of concepts and indicators as well as the design of development stage.

The concept analysis and indicator analysis phases are based on the need for AR media production as a tool to provide real visualization. At this stage, an analysis of general molecular geometry concepts was made. The next step was arranging learning indicators for AR learning media on the concept of molecular geometry. It was intended to make students know the basis of finding an appropriate molecular shape; markers can display 3D objects in both Lewis and geometric shapes in each concept.

At the design development stage, a flowchart and storyboard were made, both can provide direction in the form of links to be addressed such as the entry menu, return menu, and the media flow start to finish, so that the objects displayed followed the directions that have been made. The next step was making of 3D molecular geometry objects and markers.

9.3.1 Display of AR Application

This display provides users with information about what will be displayed on the AR media, which contains links to be addressed, namely, learning objectives, compiler profiles, and an entry menu that includes a camera view for projecting cancer cells to appear as 3D objects. An attractive display of learning media will be able to provide a change of thought stimulation, feelings, attention, and interest in the information.

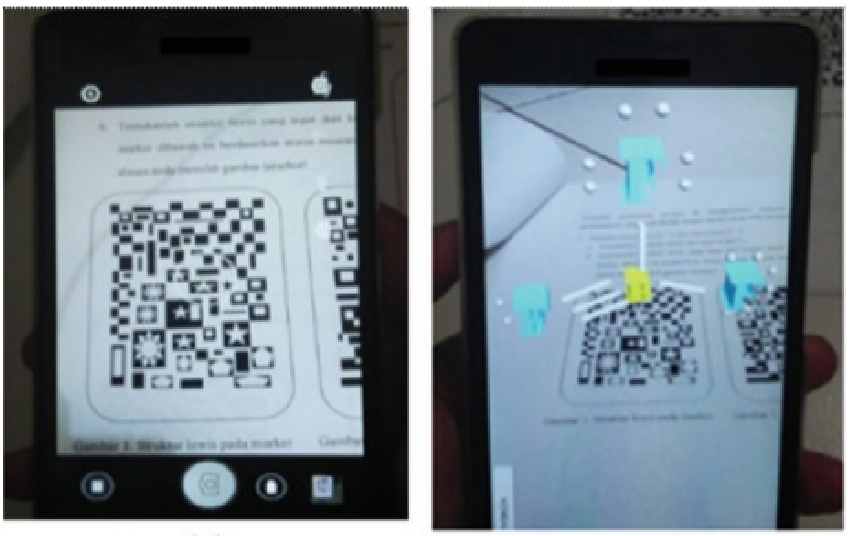
The constituent profile view aims to provide information about the data making of AR learning media making on the concept of molecular geometry. There is also a display of learning objectives that contain learning objectives on the concept of molecular geometry, namely, determining the molecular geometry of Lewis structures and formal charge, identifying the properties of compounds based on the geometric shapes of molecules, and identifying the molecular geometric shapes of various compounds. This research showed that AR learning media can modify learning objectives to be achieved and be able to adapt to the characteristics of students.

Next, there is an entry button that contains a camera view that will launch 3D objects when it is directed to the camera. This entry view provides three-dimensional submicroscopic visualization of Lewis structural and geometric shapes of molecules that have both free electrons and restricted electrons. In the use of AR media, a student worksheet has been provided, which serves as a support for AR media, in which there are some questions in line with learning indicators, each student must fill out the worksheet.

9.3.2 Worksheets and Markers

Student worksheets are supporting components of AR learning media. On the sheets, there are guidelines for the use of AR media, learning indicators, learning objectives, and several questions that guide the user (students) to understand the concept of molecular geometry. Each worksheet provides four description questions in accordance with the indicator questions that have been made, and the students were guided to determine the exact geometric shape of the molecule step by step. To get a picture or shape of 3D objects, a marker is used to support the use of AR learning media on the worksheet, and this marker can display 3D objects with suitable molecular geometry, so that the worksheet display becomes more attractive to be used. Furthermore, regarding some questions, marker shapes and 3D object shapes in the geometry concept can be seen in the following explanation.

In the first question, students were directed to count the valence electrons from the elements of Boron and Fluorine, then students were directed to choose Lewis structure images in the form of 3D objects on markers appropriately based on formal charge rules. The image of the marker and Lewis structure objects can be seen in Fig. 9.2.

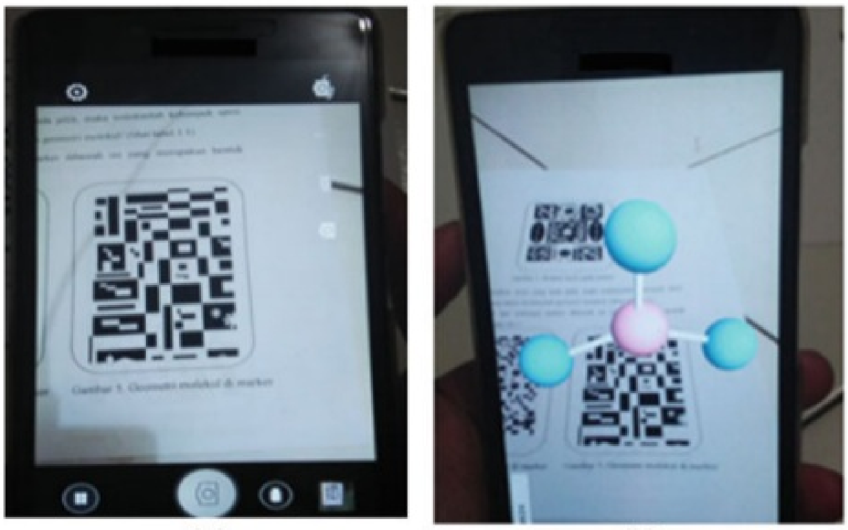


(a) (b)

Fig. 9.2 **a** Display marker before using AR media. **b** Display marker after using AR media on an Android smartphone

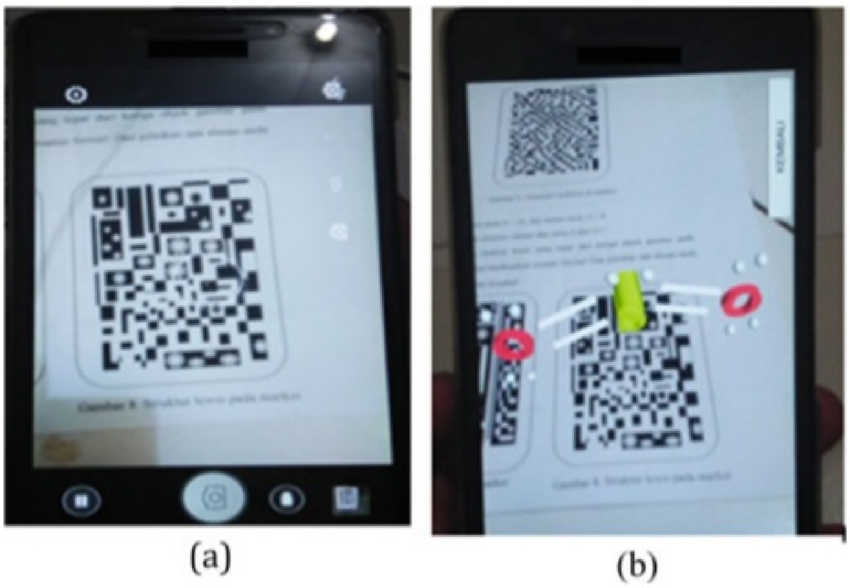
From the Lewis structure, the students must determine which species of groups can form molecular geometries based on the species groups table that has been provided. Then students were directed to choose 3D molecular geometry marker objects from BF3 molecules appropriately, and geometric shapes can be seen in Fig. 9.3.

The next step was to differentiate it based on the elements that will determine Lewis's structure and molecular geometry. Figure 9.4 is a 3D marker and object of the Lewis structure.



(a) (b)

Fig. 9.3 **a** Display marker before using AR media. **b** Display marker after using AR media on an Android smartphone



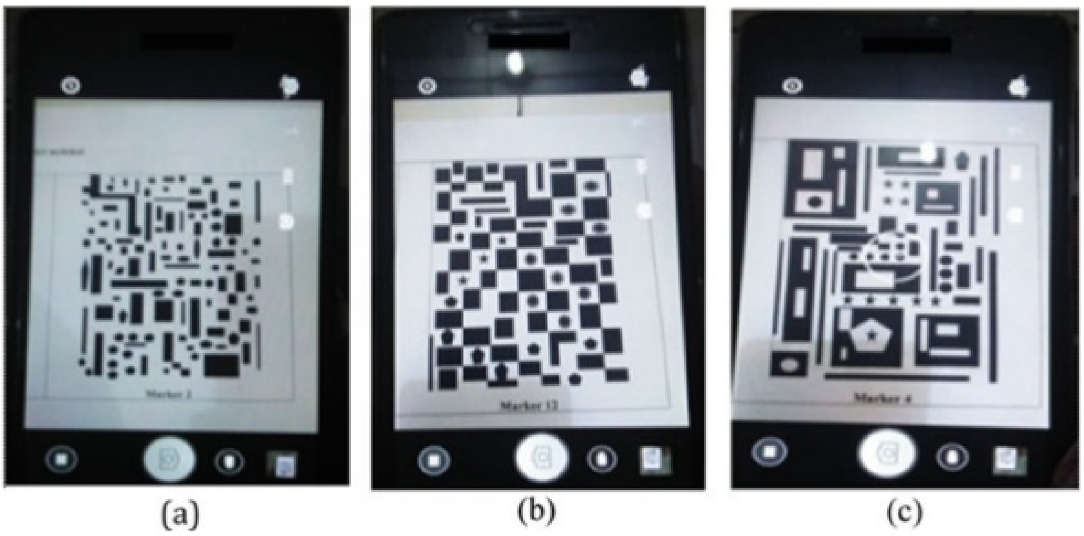
(a) (b)

Fig. 9.4 **a** Display marker before using AR media. **b** Display marker after using AR media on an Android smartphone

In the third question, students were directed to analyze differences in the molecular geometric shapes of NH_3, H_2O, and CH_4, which have the same electron geometry, namely, tetrahedral. Marker images and 3D objects can be seen in Fig. 9.5.

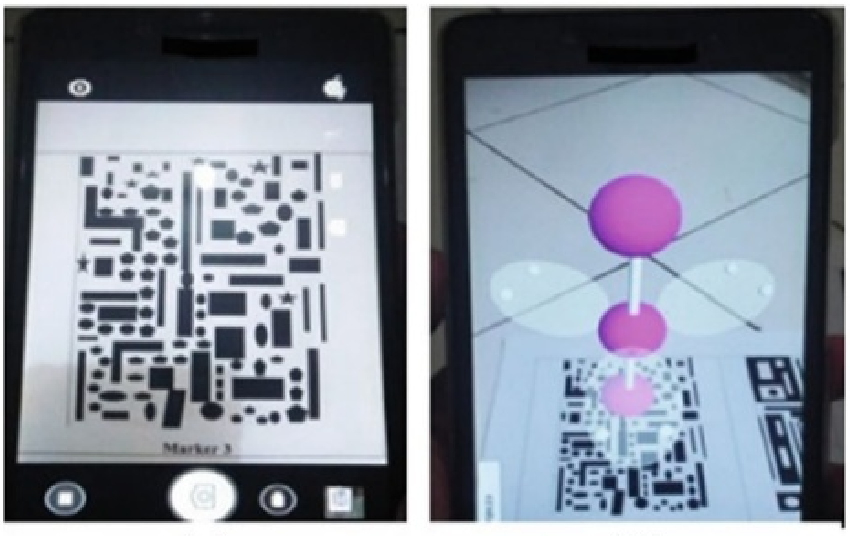
In the fourth question, students were directed to determine the various shapes of molecular geometries on markers that have been provided from several known compounds, as well as to state the reasons for choosing these markers. The visualization of markers and 3D objects can be seen in Fig. 9.6.

Based on the results of the assessment of AR learning media on the concept of molecular geometry by expert validators on four aspects (aspect of learning, aspect



(a) (b) (c)

Fig. 9.5 **a** NH_3 markers, **b** CH_4 markers and **c** H_2O markers before using AR media



(a) (b)

Fig. 9.6 **a** Display marker before using AR media. **b** Display marker after using AR media on an Android smartphone

of material substance, aspect of visual communication and aspect of software engineering) showed valid results with sufficient interpretation up to a high level with a count of 0.7–0.9. It indicates that AR learning media is appropriate to be used in learning or as teaching material to be taught. Moreover, the results of the experiment were limited to 10 students of chemistry education at Islamic State University (UIN) Sunan Gunung Djati Bandung. It showed an excellent response to the learning media that have been made, and it is proofed by the assessment given to the respondent and it has 70.83–92.5%. Based on the result of assessment, it is indicated that AR learning media is appropriate to be used as teaching materials or teaching aids.

9.4 Creating AR-Based Interactive Learning Media on the Concept of Molecular Chirality

This study used a DBR research design with a modified ADDIE model. The stages of creating media consist of three steps: analysis, design, and manufacture (Aldoobie 2015). The first stage, conceptual analysis and molecular chirality concept maps were made because the analytical study is the initial motion of a series of subsequent processes in making instructional media (Aldoobie 2015). However, creating analytic concepts takes a long time to get the problem formulation (Jannah et al. 2019). In line with Aldoobie (2015) which states that the analysis phase becomes the initial motion of the next set of processes because in creating a learning media, the creators must know part of the concepts that can be developed in learning media. Then construct learning indicators on the concept of molecular chirality. Moreover, the elaboration of learning indicators becomes a sub-indicator used in MFIs based on AR-based interactive learning media on the concept of molecular chirality.

The concept presented was based on the relation of submicroscopic representation in the presentation of AR-based interactive learning media on the concept of molecular chirality consisting of several sub-concepts, namely, object chirality, molecular chirality, chiral carbon atoms, (R) and (S) systems, diastereomers, meso compounds, chiral compounds. cyclic, and Fischer projections (Solomons et al. 2014).

At the development stage, a storyboard that contains a User Interface (UI) in the form of an AR application layout is generated, while a flowchart includes a User Experience (UX) between the students and an application that refers to the User Interface (UI) that has been made from the storyboard design stage to guide students' understanding in the concept of molecular chirality systematically (Yuntoto 2015). There were several obstacles in this stage; firstly in the design stage of storyboard display it was difficult to represent the scene layout in AR because the layout itself can change to the spot or point of view of the AR user camera so that it can interfere with student concentration (Irsyad 2016). Some solutions were provided by researchers to make students stay focused, i.e., the spot in detecting markers becomes one of the control variables in using an application, the AR camera spot must be in the upper corner facing the marker positioned horizontally with the best distance between the AR camera and marker around 20–60 cm (Irsyad 2016). The last thing done is creating 3D objects and markers.

Worksheets provided support tools for AR interactive learning media on the concept of molecular chirality and served as materials to present the results of molecular chirality visualizations. Worksheets contained guidelines to use the media, learning indicators, learning objectives, and questions. Worksheets cannot be separated from AR applications as worksheets direct students to use the AR application and to obtain results from the student learning process (Bertram et al. 2010).

9.4.1 Display of AR Media Interface

The display interface was made based on the flowchart and storyboard design, including opening page, main page (menu), using instructions, learning objectives, compiler profile, exit, and quiz. The first display presented the main page menu (menu), using directions, learning objectives, compiler profiles, exits, and quizzes.

The display of the AR molecular chirality application has several characteristics such as interactive coloring characteristics, and visualization of 3D objects. In contrasting coloring characteristics, the application display has different color combinations in letters, 3D objects, and backgrounds. It has a representative size and type of font to display on a smartphone (Norris 2018). This aims to emphasize the aesthetics of objects, so that they are easy to be operated by students (Da Silva in Blijlevens et al. 2017). For interactive characteristics, the display and the way to control it have the right frequency and it is sequentially based on the navigation presented, so that students can operate the application efficiently (Hinrichs et al. 2013).

9.4.2 Display Main Page (Menu)

Main menu interface contained menus related to molecular chirality content; the main menu button directs the user to the molecular chirality sub-concepts, namely, object chirality, molecular chirality, systems (R) and (S), diastereomers, meso compounds, cyclic chiral, and Fischer projections.

The sub-concepts contained in the main menu can guide users of AR-based interactive learning media on the concept of molecular chirality in running applications to observe the three-dimensional submicroscopic visualization of several concepts in molecular chirality material.

9.4.3 Display of Molecular Chirality Submenu

Chirality molecular elaboration consists of chiral molecules, chiral molecules, and chiral carbon atoms. The molecular chirality sub-concept is opened systematically and sequentially as the guide presented in the MFI, and the AR molecular chirality system was running by detecting markers through a smartphone camera. So the detected marker displayed 3D objects in accordance with the commands contained in the scene of each sub-concept.

9.4.4 Display Augmented Reality Markers

Markers are needed in AR-based learning media because the type of AR used in this media is a target image type that requires images to appear 3D objects. Additionally, the marker is used when students accomplish worksheet that has been made. The display of molecular chirality marker can be seen in Fig. 9.7.

Markers act as receptors (sensor receivers on AR cameras). In this study, only one marker was used for all questions. Meanwhile in the worksheet, there are questions according to the learning sub-indicators and students must fill out the worksheet. Beside it is a camera AR receptor, it also makes students easier to observe objects in 3D. Furthermore, the quality of the marker depends on the image on the marker itself, which affects the stability of the object that is raised (Cai et al. 2014).

The elements in the marker display consist of white space and image quality with sufficient resolution. White space is the space between one element and another element. It functions as a separator of each design element. It is in line with some theories that state that giving focus to the elements that want to be highlighted (Meggs 2011) and image quality with sufficient resolution can make it easier for AR cameras to do detection (Lin and Chen 2010). Additionally, the combination of accuracy of these two elements can improve students' understanding of observing the displayed 3D objects (Kamelia 2015).

Fig. 9.7 AR Chirality molecular marker

9.4.5 Display Questions on the Student Worksheet

The student worksheets consist of nine breakdown questions according to the question indicators that have been made. These questions are close to the AR molecular chirality application. The questions provided on a worksheet guide the students to understand the concept of molecular chirality, the visualization of material, and the shape of 3D objects, presented in Fig. 9.8.

The visualization display of 3D objects in this study has the details of each 3D object adjusted to the prevalence of molecules that exist both in terms of angle and color (M. Johnson and Henley 2014). In addition, 3D objects that are developed have the impression that they can be rotated as requested (M. Johnson and Henley 2014). Judging from the characteristics of the appearance and visualization of 3D objects developed by the AR molecular chirality application can be referred to as interactive media because this application is designed to actively involve student responses (Singhal et al. 2012) and also can develop submicroscopic student representations (Irwansyah et al. 2017).

9.4.6 Quiz Display

The quiz interface contains a matter of evaluating molecular chirality, which serves to determine the extent of user understanding of molecular chirality content after using AR-based interactive learning media. The quiz button directs the user to work on the evaluation questions complete with discussion.

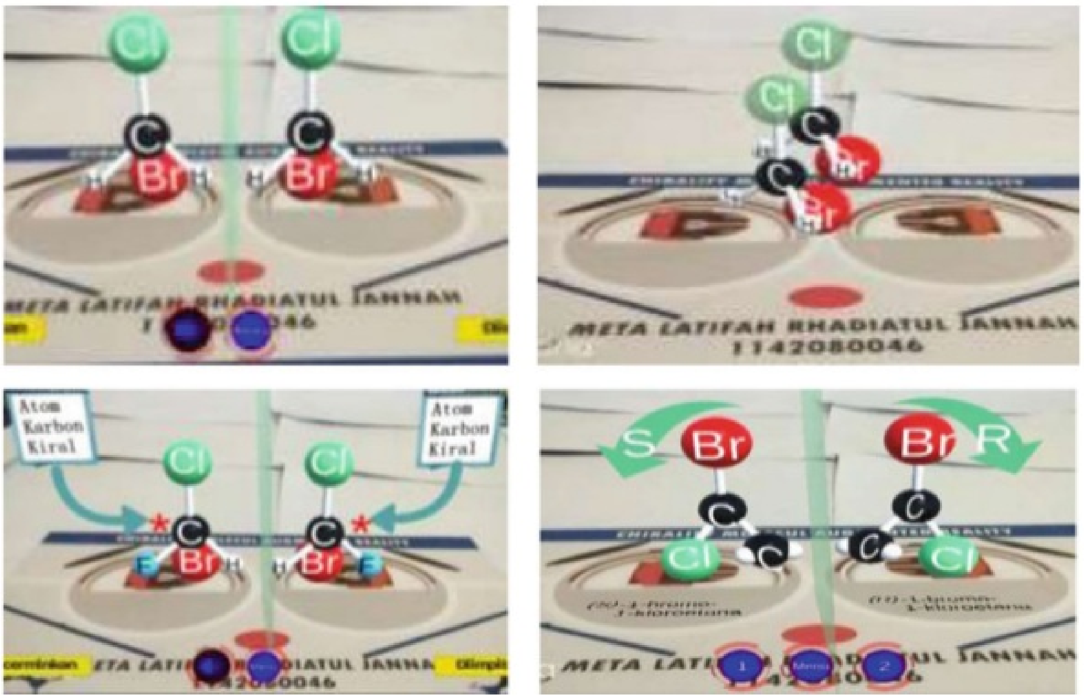


Fig. 9.8 Chiral molecules when mirrored and chiral molecules when crushed

Overall the appearance in the AR molecular chirality application has the same navigation features. After completing the development stage, the next step is the validation stage. The results of improvement are based on the results of the assessment of AR-based interactive learning media on the concept of molecular chirality by the validator and students (Septia et al. 2017). Suggestions from the validator and students were suggestions for adding instructions for the use of media in worksheet, suggestions for enlarging the size of the menu font, suggestions for color selection and size of the options button, suggestions for font sizes in applications, suggestions for improving quizzes, suggestions for adding priority order clusters to screen text, suggestions for placing object layouts in order to not obstructing screen text, and suggestions for making too effective content in the text.

The results of the feasibility test and limited experiment showed that the validator and the respondent considered that AR-based interactive learning media on the concept of molecular chirality that was made was able to meet the indicators of learning media and was suitable to use in teaching and learning process in the classroom (Irwansyah et al. 2017).

9.5 Creating AR-Based Learning Media on the Concept of Molecular Hybridization

Creating AR learning media in the formation of covalent bonds based on valence bond theory began with determining the media elements and contents that will be displayed into the application, then designing the appearance and making the application. After that, a validation test as well as a feasibility test for students was conducted by material experts and media experts.

There are two display results in each stage of creating Augmented Reality learning media in the formation of covalent bonds based on Valence Bonding Theory, in general, the result of the analysis phase and the result of design development.

The first stage of the analysis is the analysis of the needs of various journal sources on learning media, and the concept of molecular hybridization according to Salah and Dumon (2011) state that the hybridization process produces hybrid orbitals that are difficult for students to imagine. Moreover, according to Cataldo et al. (2018) hybrid orbitals are only represented by two-dimensional images. This is supported by Penny et al. (2017), which state that the molecules described in the book make the students difficult to represent it physically. It made students misunderstand in interpreting the form of hybrid orbitals (Uyulgan and Akkuzu 2016).

There were various learning media carried out on the concept of hybridization. For example manufacture of atomic model kits, this medium has a large molecular model that requires large space (Penny et al. 2017). Besides, there was also other instructional media such as the molecular model kit conducted by Smiar and Mendez (2016), the result showed that students still found difficulties in understanding the electrons contained in the molecule. Furthermore, other media, namely, three-dimensional printed molecular models was successful to help students understand atomic and hybrid orbitals, but it took more time because the three-dimensional model must be labeled (Cataldo et al. 2018). Additionally, computer technology is utilized in the concept of hybridization; for example, Macromedia flash learning media visualizes abstract concepts in the form of animations and images, which also can help students to understand about the concepts, but this media still needs improvements in appearance due to distance visibility and students lacking direct interaction with the media (Wijayanti 2018). The use of other learning media also has been carried out by displaying hybridization molecules in computers, but students have not been directly involved in them (Nassabeh et al. 2014), so it can be concluded that Molecular hybridization learning media has not been done much. Based on the previous experiment that had been done, it is imperative for us to have hybridization learning media using AR technology that hopefully can make the learning process more interactive (Carmigniani et al. 2011).

The next stage of analysis process is the analysis of concept maps and concept analysis in accordance with the curriculum. It aims to produce concepts that are appropriate with the learning media created.

Concept labels have abstract concept types and symbol concept types (Asyiah 2019). This shows that the concept of forming covalent bonds based on valence bond theory requires submicroscopic representation so that it is suitable for making AR technology-based learning media (Asyiah 2019). Furthermore, from the results of the concept analysis, a concept map was produced that aims to find out the relationship between concepts and sub-concepts.

After analyzing the concept, the next step is to compile the learning indicators used for AR learning media in the formation of covalent bonds based on the theory of valence ties in accordance with the curriculum. The material chosen was the valence bond theory. The primary competency to be achieved is that students can apply knowledge about valence bond theory and hybridization to identify the properties of compounds. Based on these necessary competencies, indicators and learning objectives are formulated to create AR learning media in the formation of covalent bonds based on valence bond theory.

The results of the analysis that have been made were used as a reference in the design phase. At the design stage, the flow of making AR learning media in covalent bond formation is based on valence bond theory in the form of flowcharts and storyboards.

The first purpose of making storyboards and flowcharts was to facilitate researchers in making AR learning media in the formation of covalent bonds based on valence bond theory. Secondly, it was intended to provide direction or guidance of the hyperlink to be addressed, such as start, return, exit menus, and others. Third, to show the flow of media from start to finish so that the menus and objects that are displayed followed the directions that had been made.

After creating storyboards and flowcharts, the next step is to develop markers and 3D objects that will be applied to the learning media of AR in the formation of covalent bonds based on valence bond theory. The results of storyboards, flowcharts, markers, and 3D objects will be used as a reference for the appearance and flow of AR media development.

9.5.1 Initial Menu Display

The initial menu display of the application contains the intended hyperlink, such as the user manual menu, KD (based competence) and aim, the writer profile, questions, exit, start menu, which includes submenus to enter the 3D object display. The initial menu display can be seen in the following Fig. 9.9.

Each display of this AR media is interconnected by using buttons, and it is intended that users can access the desired page (Kuswanto and Radiansah 2018).

This AR learning media display has several characteristics such as attractive colors and shows, and interactive. In line with Blijlevens et al. (2017), which state that attractive color designs will give users aesthetic pleasure. The characteristics of an attractive media display, in line with Nazmi (2017), which indicates an attractive media display will be able to provide stimulation of thoughts, feelings, attention, and interest in the information, so students will be encouraged to learn further. These results state that AR media is appropriate for use in learning to increase students'

Fig. 9.9 Display the initial AR media menu on an Android smartphone

interest in learning so that they also study on the formation of covalent bonds based on valence bond theory. Besides that, an attractive appearance will increase motivation in learning (Kuswanto and Radiansah 2018). On interactive characteristics, the display is equipped with various buttons making it easier for students to use the application (Hinrichs et al. 2013). Moreover, this AR media uses Android smartphone technology that most people have, so it is effortless to use if learning media is contained in smartphones (Anshari and Almunawar 2017).

9.5.2 Display Basic Competencies and Learning Objectives

The basic competencies and learning objectives display aim to provide information about what students must achieve in learning the formation of covalent bonds based on valence bond theory (Anugrahana 2016). It obtained three indicators, namely, the sub-concept of the orbital form, the hybridization process as well as the sigma bond, and pi bond which is used as sub-concepts in the indicator (Chang 2011). In line with Hartini (2013) which states that the formulation of indicators developed at least three indicators and indicator aims to provide careful direction to the material to be taught.

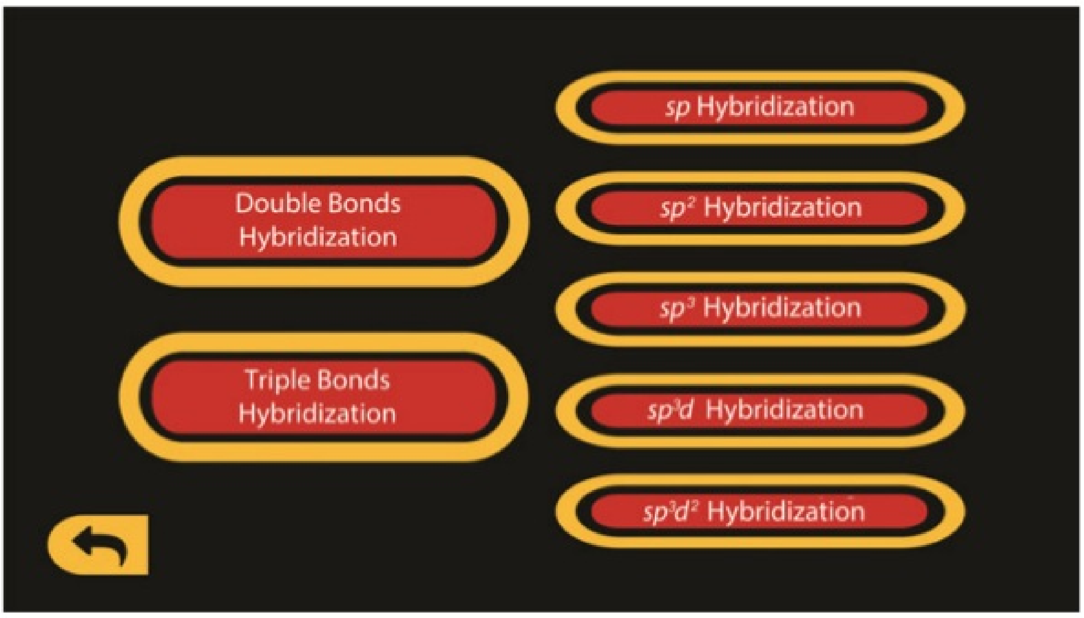


Fig. 9.10 Hybridization submenu

9.5.3 Display Main Menu (Start)

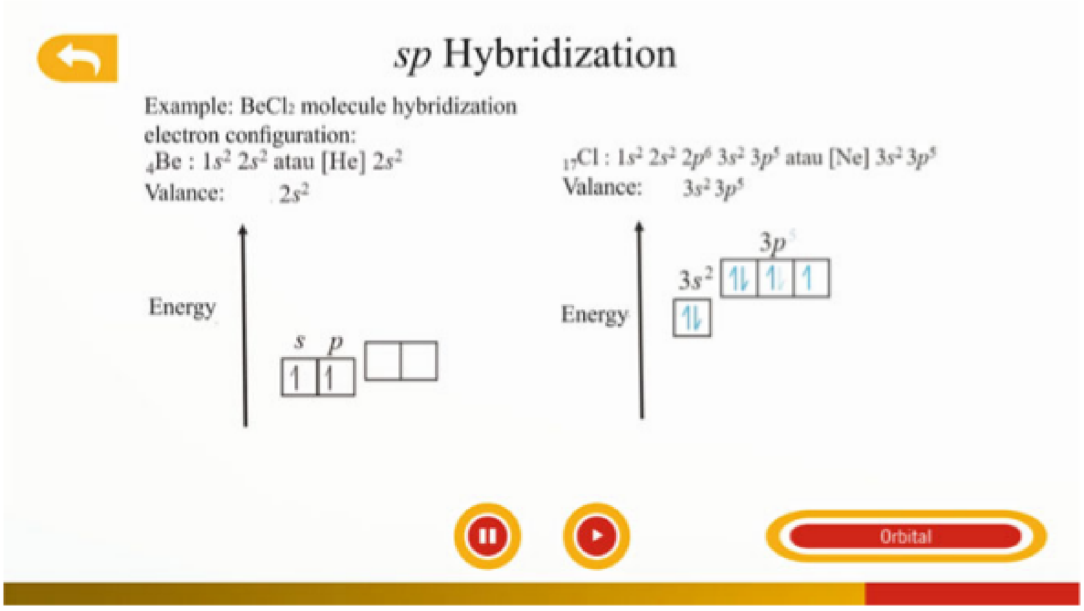
The main menu contains menus related to the content of the valence bond theory. The start button directs the user to the orbital and hybridization submenu. Orbital and hybridization submenus contained in the main menu can direct users to the next submenus to guide the user in running the application to observe the three-dimensional submicroscopic visualization of some concepts in the valence bond theory material.

9.5.4 Display of the Hybridization Submenu

Display hybridization submenu consists of sp hybridization submenu, sp^2 hybridization, sp^3 hybridization, sp^3d hybridization, sp^3d^2 hybridization, double hybridization, and triple hybridization. The hybridization submenu can be seen in the following Fig. 9.10.

9.5.5 Display Animation Hybridization Process sp

Animation of the sp hybridization process displays the sp formation of sp hybrid molecules from s and p atomic orbitals. Display animation can be seen in Fig. 9.11.



sp Hybridization

Example: $BeCl_2$ molecule hybridization
electron configuration:
$_4Be : 1s^2\ 2s^2$ atau $[He]\ 2s^2$
Valance: $2s^2$

$_{17}Cl : 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$ atau $[Ne]\ 3s^2\ 3p^5$
Valance: $3s^2\ 3p^5$

Fig. 9.11 Animation hybridization sp

In the hybridization display, there are the pause, play, back and animation progress bar buttons, and the orbital submenu. The pause button functions to stop the animation, the play button works to restart the animation, the back button functions to return to the previous menu, and the animation progress bar functions to display the extent to which the animation is running and can be clicked along the animation progress bar. The pause, play, and animation progress bar buttons aim to make it easier for users to analyze the hybridization process displayed on the animation.

This process cannot be explained on the AR camera display because AR can only display and have limitations in guidance (Mustaqim 2017). So we need guidance in the form of animation because animation can explain a concept or process that is difficult to explain with other media (Muslimin 2017), such as the concept of valence bond theory related to the hybridization process (Chang 2011).

The orbital submenu will hyperlink to the AR system. The AR system will be run by detecting markers via the Android smartphone's camera so that the detected marker will display 3D objects in accordance with the commands contained in each scene in every sub-concept. 3D objects that are displayed have an object shape that is adjusted to the normal form of the molecule in terms of angles and colors (Johnson and Henley 2015). The display of 3D objects in each sub-concept can be seen in Fig. 9.12.

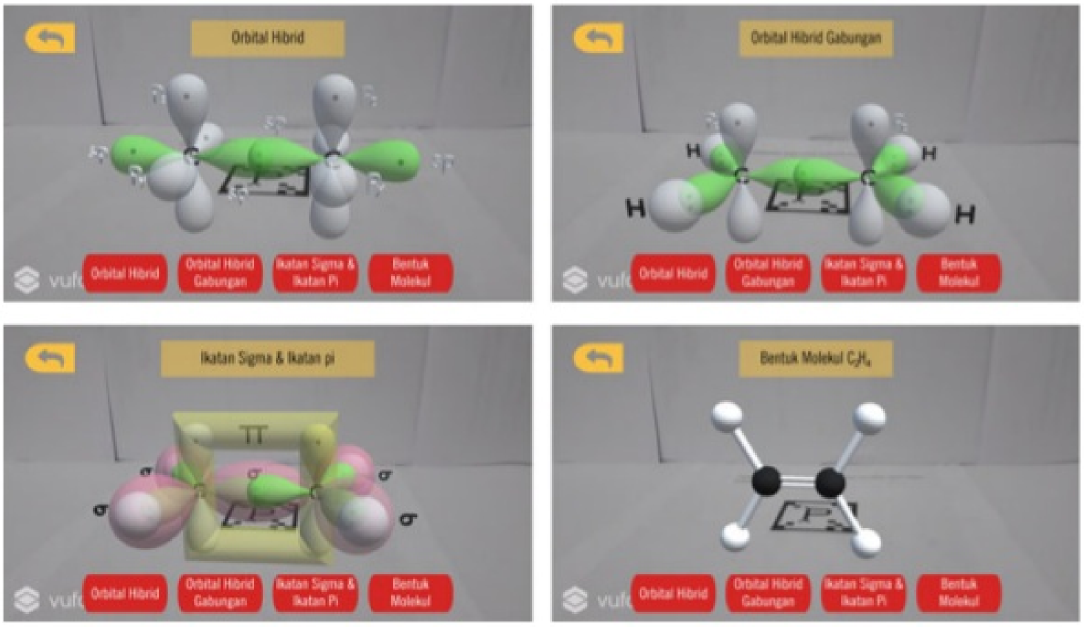


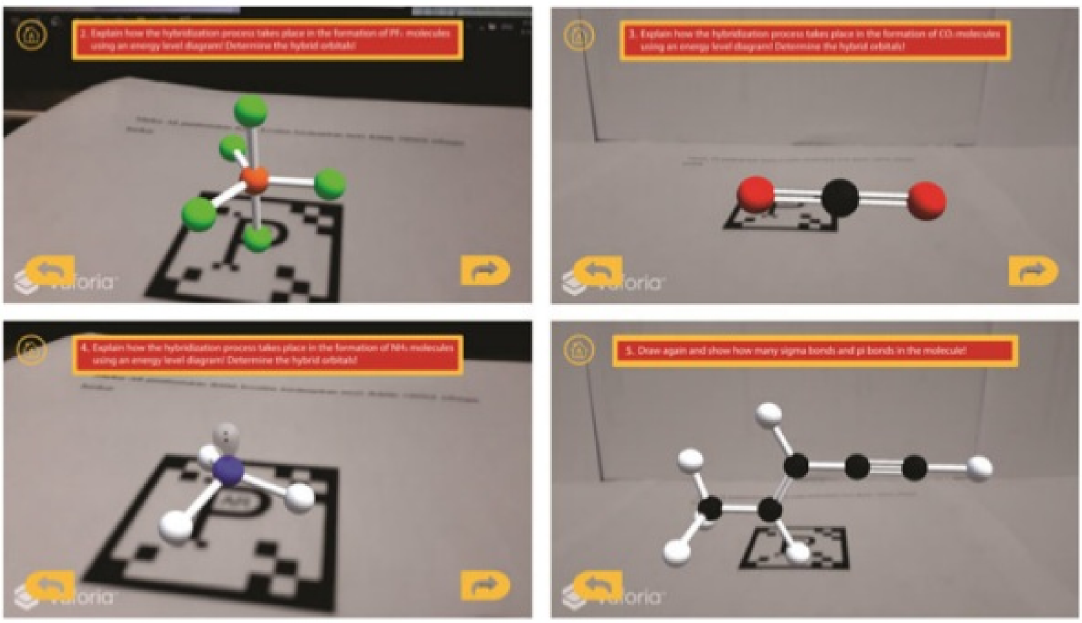
Fig. 9.12 Display of 3D objects in each sub-concept

9.5.6 *Display of Question Menu*

The questions menu contains a matter of evaluating valence bond theory. Evaluation questions were given to measure the ability of students to the extent of understanding learning through AR learning media that has been made (Kuswanto and Radiansah 2018). Questions consist of five problem descriptions that refer to the problem indicators. The question menu display can be seen in Fig. 9.13.

The type of AR that was used in this media is the type of target image whose operation requires images to bring up 3D objects. The picture is called a marker. In this study, only one marker was used to detect all 3D objects. The marker was made in the form of a square with a black and white image. Making markers that have varied colors is more interesting than black and white markers (Haryani et al. 2017). However, because 3D objects have color variations, if the marker has a color except black and white, it will interfere with the scanning process, because the marker will affect the stability of the object that appears (Cai et al. 2014). Besides that AR cameras are also needed with sufficient resolution for the scanning process on the marker. This was obtained from respondents' suggestions so that the scan can take place quickly. The improvement is by giving the camera autofocus on the application (Apriyani and Gustianto 2015). Because the density and speed of cameras and markers will increase students' understanding of observing the displayed 3D objects (Kamelia 2015). The marker display can be seen in Fig. 9.14.

The next step after making AR learning media was doing a validation test. The assessment aspects include aspects of learning, aspects of material substance, aspects of visual communication, and aspects of software engineering. So that by doing validation will obtain a learning media that is suitable for use in learning.



2. Explain how the hybridization process takes place in the formation of PF_5 molecules using an energy level diagram! Determine the hybrid orbitals!

3. Explain how the hybridization process takes place in the formation of CO_2 molecules using an energy level diagram! Determine the hybrid orbitals!

4. Explain how the hybridization process takes place in the formation of NH_3 molecules using an energy level diagram! Determine the hybrid orbitals!

5. Draw again and show how many sigma bonds and pi bonds in the molecule!

Fig. 9.13 Question menu display

Fig. 9.14 AR marker

The validation is intended to show AR learning media products and provide a validation questionnaire. The validation test was conducted on three validators. In general, AR learning media on the formation of covalent bonds based on valence bond theory is declared valid with some suggestions for improvement in certain aspects.

The feasibility test by conducting a limited experiment aims to determine the response of students to AR learning media on the formation of covalent bonds based on valence bond theory. The implementation of a limited trial began with an application given to students to be installed on a student's Android smartphone. Then students were given a guide to use media and follow the instructions of use, as stated in the instruction's menu on the AR media. Furthermore, students answer questions contained in the media. Then students were given a questionnaire to assess learning media with several aspects of the AR media. The feasibility test done by conducting a limited test resulted in several comments and suggestions from respondents. Based on the results of the feasibility of several indicators showed that this AR media can visualize the concept of abstract valence bond theory, and it is expected that the same media with different concepts can also be visualized. From all indicators obtained, it has an average value of 88.59% and it can be concluded that this media is suitable to be used as a learning media (Arikunto in Ernawati and Sukardiyono 2017).

9.6 Creating AR Learning Media on the Concept of Alkanes and Cycloalkanes

In general, based on the stages of making Augmented Reality media on the concept of alkanes and cycloalkanes, there are three display results, namely, the results of concept analysis, display of the results of design development, and validation results.

The analysis phase had been carried out in analyzing the concepts including the main concepts and sub-concepts. It was intended to produce concepts that are suitable for the learning media created. Concepts and sub-concepts have abstract concept types and symbol concept types. This shows that the concept of conformation of alkanes and cycloalkanes is a concept that emphasizes submicroscopic representations so that it is suitable for making Augmented Reality (AR) technology-based media. Furthermore, the results of the concept analysis were mapped through a concept map that aims to determine the relationship between the concepts and sub-concepts that have been analyzed.

After analyzing the concept, the next step was to compile the learning indicators used for Augmented Reality learning media. Concept labels were arranged based on the main concepts, whereas learning indicators were arranged based on sub-concepts. Learning indicators were arranged sequentially based on the level of difficulty. It aimed to facilitate students in learning the concepts of alkanes and cycloalkanes and to make learning process systematically.

At this stage, the making of learning media must pay attention to workflows based on storyboards and flowcharts. The purpose of storyboarding and flowchart is to facilitate the making of AR learning media on the concept of alkane and cycloalkanes conformation, provide direction or guidance in the form of links to the destination, such as play, exit menus, etc., and show the flow of the media start to finish so that the objects that are displayed in accordance with the directions that have been made.

After creating a storyboard and flowchart, the next step was to develop markers and 3D objects, which will later be applied to the learning media of AR on the concept of alkane and cycloalkanes conformation. The results of the storyboard, flowchart, markers, and 3D objects will be used as a reference display and flow of AR media usage. The following is the appearance and flow of the use of AR media on the concept of alkane and cycloalkanes conformation.

The menu display contains the intended links such as the hint button, profile, and play, providing the camera options for viewing 3D objects of alkane and cycloalkanes configuration on the AR media.

The purpose of making this menu display is to provide information to users about what will be displayed on the AR media. In the central display screen, there is a choice of buttons in the form of a playing display. This display aims to direct the camera display options. This display is used as an option display for users to see the 3D objects that are attached to the marker cards in the order of the numbers.

If one of these numbers is touched, an AR camera display will appear, which will then be directed to the marker so that the AR camera detects the 3D shape. In this view, there are next and previous buttons that function to see the next and previous 3D shapes of the conformational 3D shape shown. The display of each AR camera directed to the marker that matches the number of the selected marker can be seen in the following Fig. 9.15.

In each AR camera display, it presented 3D objects of different alkane and cycloalkane conformations with several different shapes as well as AR cameras from one to two display alkane conformational 3D shapes, whereas the other AR cameras display conformational 3D shapes cycloalkanes. In each 3D form show, there is a strain energy information whose function is to determine the conformational stability of ethane. However, 3D objects are not presented with a description of the name

Fig. 9.15 Display each AR camera that is directed to each marker that matches the number selected

of the conformation so that users can determine their name by just looking at the shape. The function of next and previous buttons on the AR camera display is to help the user (students) in learning the amount of conformation of each compound, both alkanes and cycloalkanes.

Spreadsheets are one of supporting component for running Augmented Reality applications on various Android smartphones. On the worksheet, there are guidelines for the use of AR media, learning indicators, learning objectives as well as several questions that guide the user (students) to understand the concepts of alkane and cycloalkanes conformation. Before making a worksheet, first, we made a grid of questions that are useful as a reference in formulating a worksheet following the AR media that has been made. Inside the questions grid, there are question indicators that are in line with the learning indicators, questions in accordance with problem indicators, and the level of difficulty of the questions and answers, and scores as a reference in assessing students' work. This worksheet is very helpful in building students' understanding of the concepts of alkane and cycloalkanes conformation so that learning becomes more meaningful (Lan et al. 2013).

Question worksheets were made and it referred to indicators. The worksheets consisted of six questions, each had little description questions following the indicator questions that have been created. The user (student) is guided in stages on how to determine the conformation of each compound, describe conformation and how to determine the stability of conformation, and explain the relationship between conformational forms and the stability of the alkane and cycloalkane conformations.

The worksheet was along with a supporting marker card using AR learning media, which amounts to nine. This marker card can display 3D objects of alkane and cycloalkanes conformation accompanied by energy information of each conformation if the camera is directed at the marker, as explained in the previous discussion. The use of the marker card is to follow the instructions or questions listed on the worksheet.

Validation was carried out by showing the learning media products and providing three pieces of instruments, namely, AR learning media worksheets, MFI assessment rubric, and validation questionnaire sheets. The results of the validation were conducted on three validators. In general, the results of the validation of AR learning media on the concept of alkanes and cycloalkanes were valid with some suggestions for improvement in certain aspects.

The results of the feasibility test of the Augmented Reality learning media on the concept of alkane and cycloalkanes conformation showed that the learning media of AR on the concept of alkane and cycloalkanes conformation gets sufficient value on the indicator of the efficiency of product use in terms of time. It showed that AR learning media on the concept of alkane and cycloalkanes conformation is quite feasible and can streamline learning time (Sudjana 2009). However, to be more efficient in learning time, improvements and additions are needed so that learning runs effectively. This was explained (Mahnun 2012) that the learning media that had been made needed to be further improved so that the learning media was more efficient, reliable, and suitable to be used. Furthermore, the media makes students easy to develop their abilities and interests.

9.7 Conclusion

Research showed that Augmented Reality (AR) as a learning media is helpful in chemistry teaching and learning particularly for abstract and complex concepts that need a visualization in the learning process such as the concept of metal crystal, molecular geometry, molecular chirality, hybridization, and conformation of alkanes and cycloalkanes.

Result of feasibility test of AR showed that it has 72.5–88.33% for metal crystal material, 70.83–92.5% for molecular geometry material, and molecular chilarity has 90.12% in average. Furthermore, feasibility result of AR for hybridization is 83.33–97.50% and it is 75–87.5% for conformation of alkanes and cycloalkanes.

Based on the result above, we can conclude that AR can be used as a learning media in chemistry teaching and learning process since it helps students to comprehend the invisible concepts. Moreover, it is expected that AR in chemistry education will be continually developed in other submicroscopic concepts and hopefully the improvement media could be more optimal in system without markers so that it can be used easier without scanning.

References

Aldoobie N (2015) ADDIE model. Am Int J Contemp Res 5(6)

Anshari M, Almunawar MN (2017) Smartphones usage in the classrooms: learning aid or interference ? Educat Informat Technol 22(6):3063–3079

Anugrahana A (2016) Peningkatan Kompetensi Dasar Mahasiswa Calon Guru SD pada Mata Kuliah Pendidikan Matematika dengan Model Pembelajaran Inovatif. J Penelitian 20(2):182–187

Apriyani M E, Gustianto R (2015) Augmented reality sebagai Alat Pengenalan Hewan Purbakala dengan Animasi 3D menggunakan Metode Single Marker. J Infotel 7(1)

Arsyad (2007) Media Pembelajaran. PT Raja Grafindo Persada, Jakarta

Bertram WC et al (2010) Using media in teaching

Asyiah et al (2019) The making augmented reality technology-based learning media in molecular hybridization concept. J Phys: Conf Ser 288(1):012068. https://doi.org/10.1088/1757-899X/288/1/012068

Blijlevens J et al (2017) The Aesthetic Pleasure in Design Scale : The Development of a Scale to Measure Aesthetic Pleasure for Designed Artifacts. Psychology of Aesthetics, Creativity, and the Arts 11(1):86–98

Cai S et al (2014) Computers in Human Behavior A case study of Augmented Reality simulation system application in a chemistry course. Comput Hum Behav 37(5):31–40. https://doi.org/10.1016/j.chb.2014.04.018

Carmigniani J et al (2011) Augmented reality technologies, systems and applications. Multimedia Tools and Applications 51(1):341–377

De CR et al (2018) Hands-On Hybridization: 3D-Printed Models of Hybrid Orbitals. Journal of Chemistry Education 95(9):1601–1606

Chang R (2011) General Chemistry The Essential Concepts, 6th edn. McGraw-Hill, Rockefeller Center

Darmawan D (2012) Teknologi Pembelajaran. PT Remaja Rosda Karya, Bandung

Ernawati, I, Sukardiyono T (2017) Uji Kelayakan Media Pembelajaran Interaktif pada Mata Pelajaran Administrasi Server. Electronics, Informatics, and Vocational Education 2(2)

Han S (2018) How does The Smartphone Usage of College Students Affect Academic Performance? Journal of Computer Assisted Learning: 1–10.

Hartini S (2013) Pengembangan Indikator dalam Upaya Mencapai Kompetensi Dasar Bahasa Indonesia di Sekolah Menengah Atas Kabupaten Karanganyar Jawa Tengah. In Universitas Muhammadiyah Surakarta. Surakarta, Indonesia, p 198–214

Haryani P et al (2017) Augmented Reality (AR) Sebagai Teknologi Interaktif dalam Pengenalan Benda Cagar Budaya Kepada Masyarakat. Jurnal SIMETRIS 8(2):807–812

Hinrichs U et al (2013) Interactive Public Displays. IEEE Comput Graphics Appl 33(2):25–27

Irsyad, S (2016) Aplikasi Augmented Reality Sebagai Media Simulasi Ikatan Kimia Berbasis Android Menggunakan Metode Fast Corner Detection. In Universitas Islam Negeri Maulana Malik Ibrahim Malang

Irwansyah FS et al (2017) The Development of An Augmented Reality (AR) Technology-based Learning Media in Metal Structure Concept. Ideas for 21st Century Education. Taylor & Francis Group, London, pp 233–238

Irwansyah FS et al (2018) Augmented Reality (AR) Technology on the Android Operating System in Chemistry Learning. IOP Conference Series: Materials Science and Engineering 288(1):012068. https://doi.org/10.1088/1757-899X/288/1/012068

Isberto M (2018) The History of Augmented Reality. https://androbuntu.com/2018/12/29/pengertian-augmented-reality/. Accessed 3 May 2019

Jannah M L R et al (2019) Making Interactive Learning Media Based on Augmented Reality on the Concept of Molecular Chirality Making Interactive Learning Media Based on Augmented Reality on the Concept of Molecular Chirality. In Journal of Physics: Conference Series IOP

Johnson M, Henley J A (2014) Learning 2D Game Development with Unity: A Hands-On Guide to Game Creation. Retrieved from https://books.google.com/books?id=dgTVBQAAQBAJ&pgis=1

Johnson M, Henley J A (2015) Learning 2D Game Development with Unity: A Hands-On Guide to Game Creation

Kamelia L (2015) Perkembangan Teknologi Augmented Reality Sebagai Media Pembelajaran Interaktif Pada Mata Kuliah Kimia Dasar. Jurnal Istek 9(1)

Kuswanto J, Radiansah F (2018) Media Pembelajaran Berbasis Android pada Mata Pelajaran Sistem Operasi Jaringan Kelas XI. Jurnal Media Infotama 14(1)

Lan C, et al (2013) Mobile Augmented Reality in Supporting Peer Assessment: An Implementation in a Fundamental Design Course. In IADIS International Conference on Cognition and Exploratory Learning in Digital Age (CELDA 2013), Celda

Lin H, Chen T (2010) Advanced Concepts for Intelligent Vision Systems. Computers & Graphics 26(3)

Mahnun N (2012) Media Pembelajaran (Kajian terhadap Langkah-langkah Pemilihan Media dan Implementasinya dalam Pembelajaran). Jurnal Pemikiran Islam 37(1)

Martin J et al (2018) Augmented reality dalam pendidikan 4.0. In: 2018 IEEE-13 International Scientific dan Konferensi Teknis Ilmu Komputer dan Teknologi Informasi, CSIT

Meggs P B (2011) The Elements of Graphic Design. Type and Image: the Language of Graphic Design

Molenda M, Januszewski A (2008) Educational technology: A definition with commentary. In Association for Educational Communications and Technology (AECT)

Muslimin MI (2017) Pengaruh Penggunaan Media Pembelajaran Video Animasi terhadap Hasil Belajar Pendidikan Kewarganegaraan Kelas II SD. E-Jurnal Prodi Teknologi Pendidikan 6(1):26–34

Mustaqim I (2017) Pemanfaatan Augmented Reality Sebagai Media Pembelajaran. Jurnal Pendidikan Teknologi Dan Kejuruan. https://doi.org/10.23887/jptk-undiksha.v13i2.8525

Nassabeh N et al (2014) Dissociation of the Ethyl Radical: An Exercise in Computational Chemistry. J Chem Educ 91(8):1248–1253

Nazmi M (2017) Penerapan Media Animasi untuk Meningkatkan Minat Belajar Peserta Didik pada Mata Pelajaran Geografi di SMA PGII 2 Bandung. Jurnal Pendidikan Geografi 17(1):48–57

Norris CB (2018) Academic Writing in English. University of Helsinki, Language Services

Oh S, Byun Y (2012) The Design and Implementation of Augmented Reality Learning Systems. In: 2012 IEEE/ACIS 11th International Conference on Computer and Information Science, p 651–654

Penny MR et al (2017) Three-Dimensional Printing of a Scalable Molecular Model and Orbital Kit for Organic Chemistry Teaching and Learning. Journal of Chemistry Education 94(9):1265–1271

Sadiman AS et al (2009) Media Pendidikan: Pengertian. Pengembangan dan Pemanfaatannya, Rajawali Pers, Jakarta

Salah H, Dumon A (2011) Research and Practice Conceptual Integration of Hybridization by Algerian Students Intending to Teach Physical Sciences. Chemistry Education Research and Practice 12(4):443–453

Septia T et al (2017) Validation of Lectora based interactive module to improve the ability of junior high school students spatial in learning Geometry. Retrieved from https://umindanao.edu.ph/journal/wpcontent/uploads/2018/01/UM20172112_Validation-of-Lectora-based-interactive-modu.pdf

Singhal S et al (2012) Augmented chemistr : Interactive Education System 49(15)

Smiar K, Mendez JD (2016) Creating and Using Interactive, 3D-Printed Models to Improve Student Comprehension of the Bohr Model of the Atom, Bond Polarity, and Hybridization. Journal of Chemistry Education 93(9):1591–1594

Smith K, Nakhleh MB (2011) University Students' Conceptions of Bonding in Melting and Dissolving Phenomena. Research and Practice 12(6):398–408

Solomons TWG et al (2014) Organic chemistry. Petra, United States of Americ

Sudjana N (2009) Media Pembelajaran. Sinar Baru Algensindo, Bandung

Udin M N et al (2016) Perancangan Media Pembelajaran Menggambar Teknik Dengan Menggunakan Macromedia Flash. Indonesian Journal of Civil Engineering Education 2(1)

Uyulgan MA, Akkuzu N (2016) An insight towards conceptual understanding: looking into the molecular structures of compounds. Acta Didactica Napocensia 9(4):49–70

Wijayanti F (2018) Pembuatan Media Animasi untuk Topik Hibridisasi dengan Program Macromedia Flash. Jurnal Ilmu Kimia Dan Terapan 2(1):11–16

Yuntoto S (2015) Pengembangan Aplikasi Android Sebagai Media Pembelajaran Kompetensi Pengoperasian Sistem Pengendali Elektronik Pada Siswa Kelas XI SMKN 2 Pengasih

Zan N (2015) The effects of smartphone use on organic chemical compound learning. US-China Educat Rev A 5(2):105–113

2020 - Book Chapter AR Front cover + Content.pdf

ORIGINALITY REPORT

10%	5%	6%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

3%

★ F S Irwansyah, Y M Yusuf, I Farida, M A Ramdhani. "Augmented Reality (AR) Technology on The Android Operating System in Chemistry Learning", IOP Conference Series: Materials Science and Engineering, 2018

Publication

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		