



Designing Interactive Learning Application Using Markerless Augmented Reality on Evolution of Atomic Theory Material

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Abstract

To increase student understanding and enrich the learning experience, research was conducted with the aim of designing a interactive learning application using markerless augmented reality as an interesting solution. This is because learning applications use augmented reality in evolution of atomic theory material into a form of education that combines innovative technology with personalized learning, so that it can help create a generation that is technologically skilled and ready to face future challenges. This research includes educational design research using Plomp development model, including preliminary research stage by doing the needs and context analysis, literature review, and theoretical framework and prototyping stage, including initial plan and self evaluation. For the results based on preliminary research data and the prototyping phase, it can be concluded that the design of learning applications using Plomp development model which produces prototype II that has been successfully run as expected according to the design based on the results of analysis in preliminary research. This application prototype is hoped to be continued to produce learning applications that can be used in schools to support chemistry learning.

Keywords: Designing, Interactive Learning Application, Augmented Reality, Evolution of Atomic Theory

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INTRODUCTION

Technology in education has brought about major changes in the way learning is delivered (Tateno et al., 2019). One of the technology that has the opportunity to enhance the learning experience is Augmented Reality. Augmented Reality combines virtual elements with the real world, creating interactive and immersive learning experiences. Augmented Reality based on its use can be divided into marker-based Augmented Reality and markerless Augmented Reality. Markerless Augmented Reality is an approach to AR that allows users to experience virtual elements in a real environment without the need of markers. By using this technology, learning applications can create 3D models of atomic structures that students can interact with.

The application of markerless Augmented Reality technology in learning is also in line with the development of Society 5.0, which emphasizes the use of technology to achieve a human-centric society. In Society 5.0, education focuses on developing individual potential and empowering students to become innovators, creative and able to adapt to technological changes (Novita & Rahayu, 2021). This use of technology in education can help create a generation that is technologically skilled and ready to face the challenges of future. Interactive learning applications using markerless Augmented Reality on Atomic Evolution Theory material can be a form of education that combines innovative technology with personalized learning, enabling students to learn in an interesting, interactive, and relevant way to the real world (Turkan et al., 2017). As in the research of Supriono & Rozi (2018) which showed the

results that the developed learning media for chemical molecular shapes using marker based Augmented Reality based on Android can run well from the aspect of functional suitability and the research of Rosma Aryani et al (2019) which stated that students' interest in learning increased due to the application of guided inquiry learning assisted by marker based Augmented Reality media. However, in the developed application, there is no interactive learning process that is oriented towards the process of discovering concepts by students. In addition, the developed application still uses marker assistance in physical form, such as paper. Meanwhile, according to (Sung et al., 2016) markerless Augmented Reality system with deformable objects can overcome the weakness of traditional marker based augmented reality system with rigid object that are not suitable to apply to other various fields including education area.

The use of Markerless Augmented Reality in education can be applied to various subjects, one of which is chemistry. Augmented Reality in chemistry education has great potential to increase student understanding and interest (Yildirim, 2020). By utilizing AR technology, students can experience more interesting, interactive, and immersive learning in learning complex chemical concepts. Augmented Reality in chemistry education is able to present 3D models from abstract concepts and experimental simulations complemented by animation. One of the chemistry materials that contains many abstract concepts and the discovery process that involves experiments is the material for the Evolution of Atomic Theory.

The use of Markerless Augmented Reality technology in Evolution of Atomic Theory material has the opportunity to create better learning. One of the main advantages of Augmented Reality on Evolution of Atomic Theory material is its ability to present 3D models of atomic models from each atomic theory. Students can use electronic devices such as smartphones or tablets to view atomic models directly in their room. Students can also rotate, zoom, and examine the details of 3D objects with their own hands via devices. That way, they can learn about the development of atomic theory more clearly and deeply. This realistic visualization helps students to better understand the abstract developmental concepts of atomic theory (Köse & Güner-Yildiz, 2021). Another benefit of using Markerless AR technology on atomic theory material is to display experiments on the process of discovering atomic subparticles without having to scan markers. Students can observe the discovery process of the sub-particles that make up the atom that is happening in real time, observe the movement of the particles and their consequences by using Augmented Reality devices. Thus, students can be involved indirectly in the discovery environment of atomic subparticles.

AR technology can be combined with quizzes that guide students to find concepts based on observations of 3D objects in the form of learning applications. Students can be actively involved, collaborate with group mates, and get direct feedback on the answers to their quizzes. This can create a fun learning experience and motivate students to continue to develop their understanding of chemistry. These learning apps can also provide audio and visual explanations that help students understand complex concepts better.

Based on the opportunities provided by the combination of technology with Augmented Reality, research was carried out with the aim of designing interactive learning application prototype using markerless Augmented Reality as a solution to increase student understanding and enrich learning experiences. As in research Supriono & Rozi (2018) and Rosma Aryani et al (2019) which state that applications with augmented reality for chemistry subject are appropriate for use in schools and increase student interest in learning. However, the developed application has not been equipped with material that guides students to find concepts and still uses markers to be able to bring up 3D objects to be observed. Therefore, this study aims to design a learning application with markerless augmented reality which is equipped with a learning process that guides students to discover concepts through doing quizzes and direct and real observations of 3D objects that can be accessed in one application without additional paper as a marker.

METHOD

This research includes Educational Design Research using the Plomp model. This research with the Plomp model includes two stages, namely the preliminary research and the prototyping stage. Preliminary research aims to determine and define the requirements in the development of a product. This research is limited to self-evaluation activity to generate the fully functioned prototype of application. Formation of a prototype is the design stage by realizing the intervention of the product being developed. The subjects of this study were 5 teachers from SMAN 7 Padang, SMAN 10 Padang, and SMA Pembangunan Lab UNP and 72 students from Phase E of SMAN 7 Padang, SMAN 10 Padang, and SMA Pembangunan Lab UNP. The object of this study is the interactive learning application using markerless Augmented Reality on evolution of atomic theory material. The subject Stages on Preliminary Research is given on Figure 1.

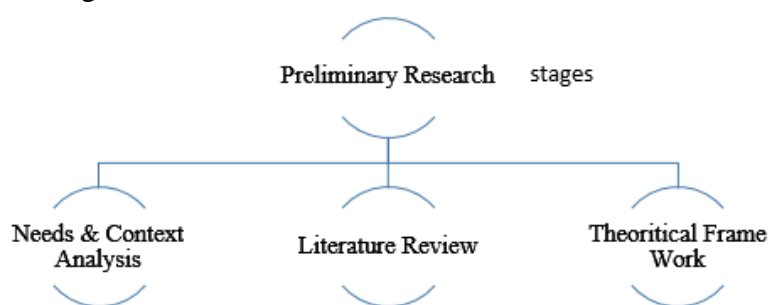


Figure 1. Stages on Preliminary Research

Needs and Context Analysis

Needs analysis in this study is to look at the views of teachers and students regarding the current situation which includes what works well, what must be changed, and the characteristics of the expected situation. Context analysis is aimed at exploring the problem environment and mapping the scope for innovation. The method used in needs and context analysis is triangulation to increase the quality of data and to avoid the influence of any specific researcher, namely by combining the distribution of questionnaires to teachers and students as well as interviews with teachers and document analysis. The data to analyze obtained from 5 teachers from SMAN 7 Padang, SMAN 10 Padang, and SMA Pembangunan Lab UNP and 72 students from Phase E of SMAN 7 Padang, SMAN 10 Padang, and SMA Pembangunan Lab UNP, also from the learning media that is used by the teachers.

Literature Review

The purpose of a literature review is to gain a deeper understanding of the research topic, identify gaps and research opportunities, support research arguments and approaches, develop an appropriate theoretical framework. Literature review is done by finding references related to research activities. The references used are articles from indexed journals.

Theoretical Framework

The results of the needs and context analysis along with the results of the literature study are set forth in a conceptual framework by identifying, detailing, and compiling the main concepts needed in designing interactive learning applications using markerless augmented reality on the evolution of atomic theory material.

The stages in the Prototyping Phase is given on Figure 2.

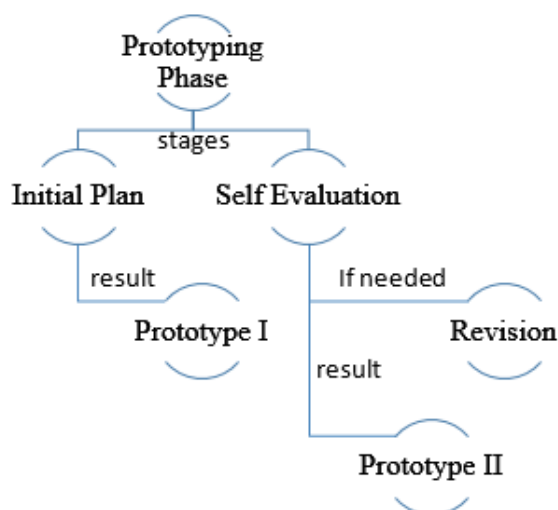


Figure 2. Stages on Prototyping Stage

Initial Plan

The initial design of the product is based on preliminary research. At this stage, the application begins to be designed starting from the software engine used, the appearance of the application, and the application of the systematic program. This initial design stage resulted in prototype I.

Self Evaluation

Self-evaluation was carried out using the check-list method to see the completeness of prototype I. This initial design stage resulted in prototype II. The resulting Prototype II will determine whether the prototype application can run properly or not.

RESULTS AND DISCUSSION

Application design using the Plomp development model in this study aims to produce prototype II to determine whether the application design can fully function according to design based on the results of preliminary research analysis.

Needs and Context Analysis

The goal of needs and context analysis is to deeply understand user needs and the context in which augmented reality Augmented Reality applications will be used. By understanding user needs and usage contexts, developers can design and develop AR applications that are more relevant, functional and attractive to users. The data were obtained through questionnaires and interviews with five chemistry teachers from SMAN 7 Padang, SMAN 10 Padang, and SMA Pembangunan Lab UNP.

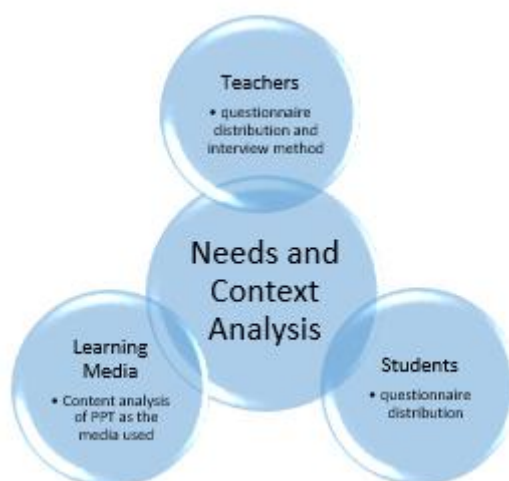


Figure 3. Needs and Context Analysis

The evolution of atomic theory is a fundamental part of chemistry. Studying the structure of atoms and their subatomic particles is essential for understanding the properties of matter and the principles that govern chemical reactions. Evolution of atomic theory material contains factual, conceptual, and procedural knowledge. Judging from its nature, most of the concepts of this material are abstract. Abstract concepts in atomic theory material make it difficult for students to understand the material being taught, one of the factors being constrained in visualizing these abstract concepts. This is in line with data obtained from 72 students in phase E for the 2022/2023 school year, that 66 of them experienced problems visualizing abstract concepts in atomic theory material.

One of the reasons for the low number of students who can understand concepts is that teachers rarely use media that display abstract concept images well in learning. The use of visual media is more attractive for students to continue the learning process because visual influences have more impact on the ease of understanding material (Safitri & Sa'dudin, 2019). Based on distributing questionnaires to 5 teachers, 100% of teachers used PowerPoint media in the learning process of atomic theory development, where the media contains a lot of explanatory text and contains unclear images. According to Siirtola et al (2014) media that can support the presentation is at least accompanied by clear visualization and concise text descriptions. The use of media with non-concise explanatory texts and unclear visualizations causes 70% of students to prefer memorizing each material in the media provided and rewriting it in notebooks before carrying out cognitive tests, in this case daily tests and exams. Learning media has an influence on students' cognitive learning outcomes (Tanjung, 2015). Four out of five teachers stated that less than 25% of the total students could achieve scores above the minimum score given. This explains that the media used by teachers is not yet effective for use, because a media is said to be effective if $\geq 75\%$ of students achieve the specified minimum score (Heriyanto et al., 2013).

Choosing the right learning media will attract students' interest in learning and be able to make students active in learning. Four out of five teachers stated that the media used in learning the development of atomic theory did not attract the attention of students, so that students were less active during the learning process of developing atomic theory. This shows that the selection of media used in learning the development of atomic theory used is not appropriate to support student-centered learning. Mobile technologies offer opportunities to facilitate student-centered learning (Chen & Tsai, 2021). 100% of students questioned stated that they used personal devices at school, and this was supported by data that 5 out of 5 teachers allowed the use of devices to support the learning process at school. Even though gadgets have been used in the learning process for the development of atomic theory, in fact most students use gadgets to answer questions by accessing quick and instant answers via a browser. The high use of gadgets among students can be used as one of the technology-based media that guides students to find concepts to support learning both in class and independent learning outside of school. One technology that utilizes the use of devices with student-oriented learning is an integrated learning application Augmented Reality.

Literature Review

Literature Review aims to find and understand the sources associated with the development activities carried out. Literature review is carried out by finding references related to the activity of designing interactive learning applications using augmented reality without markers on the material of atomic theory evolution.

Learning with Augmented Reality media increases students' interest in learning and understanding of students' concepts. This is supported by the research of Rosma Aryani et al (2019) which showed that the application of guided inquiry learning assisted by Augmented

Reality media had an effect on increasing students' interest in learning, understanding students' concepts, and there was a correlation between interest in learning and understanding concepts that was equal to 0.8%. Interactive multimedia based on mobile learning is feasible to use. This is supported by Rorita et al's research (2018) which results of the study show that mobile-based multimedia is feasible to use. The use of Augmented Reality media can improve students' cognitive learning outcomes. This is supported by Acesta & Nurmaylany's (2018) which showed that there was an increase in learning outcomes between classes using Augmented Reality media and classes using two-dimensional image media. Augmented Reality media increases student enthusiasm. This is supported by the research of Wildan et al (2023) which results of the study show that the use of Augmented Reality gives positive results for students to increase the enthusiasm of students. Augmented Reality media in chemistry learning can improve students' 4C (Critical Thinking, Creative Thinking, Collaboration, and Communication) skills. This is supported by Elisa & Wiratmaja's research (2019) which results of the study show that appropriate learning media are applied in theoretical and abstract learning and increase student learning motivation in theoretical and abstract courses and are able to provide different experiences so that they can be used to train students' 4C skills as skills that are urgently needed in the 21st century.

Theoretical Framework

Theoretical framework disusun berdasarkan hasil needs and context analysis dan literature review. Theoretical framework is given on Figure 2.

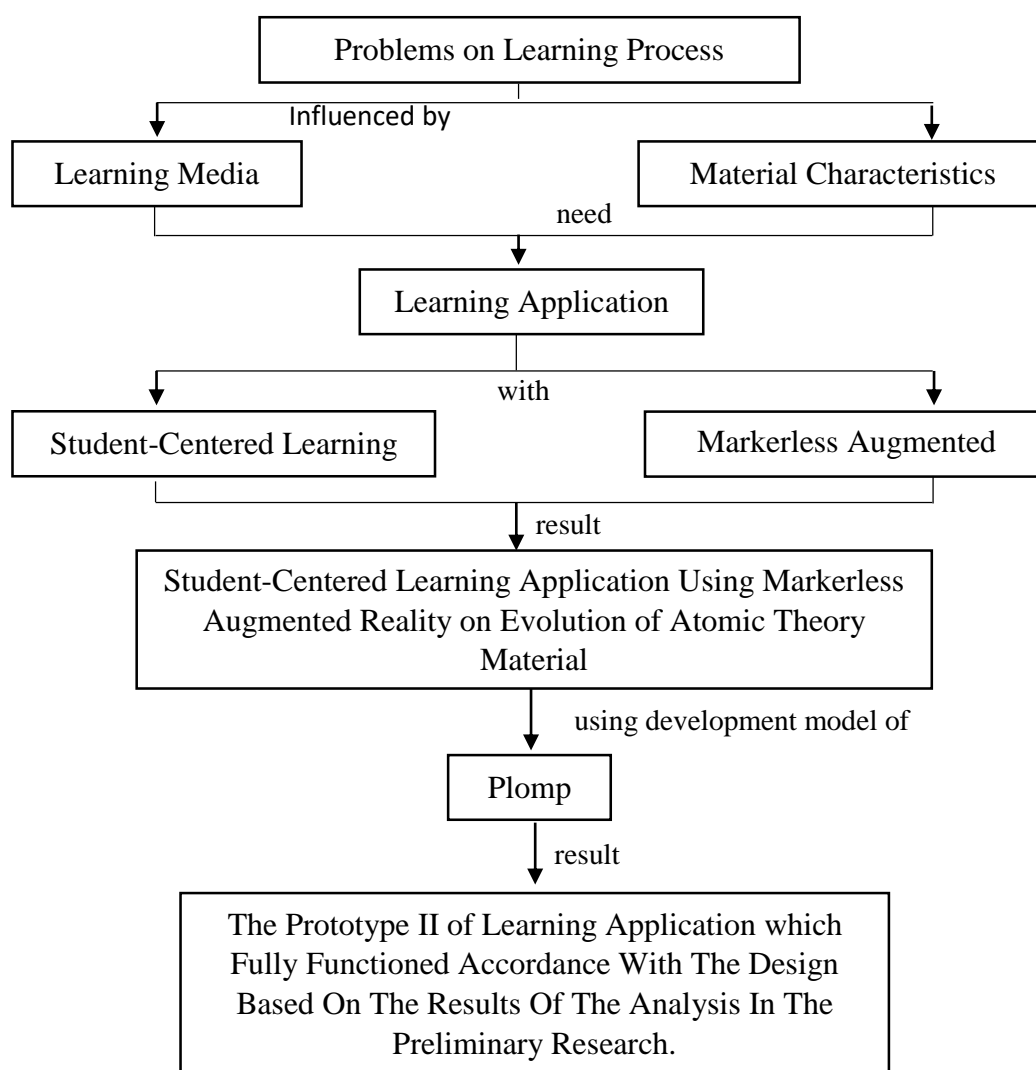


Figure 4. Theoretical Framework

Initial Plan

The development of the application using markerless Augmented Reality involves several pieces of software, namely Unity 3D, EasyAR, Visual Studio, and Blender. unity is used as the main application development studio by combining animations on each button used. EasyAR is the party that provides markerless AR which is then connected to the unity program. Blender is an application that provides services for creating 3D objects that are inputted into the AR program. Visual studio is a software used to write C# script code. Adobe Illustrator is vector-based software that is used to create graphic designs that are inputted into application programs. It is important to design the activity flowchart to understand the application program. The activity flowchart is presented in the figure 3.

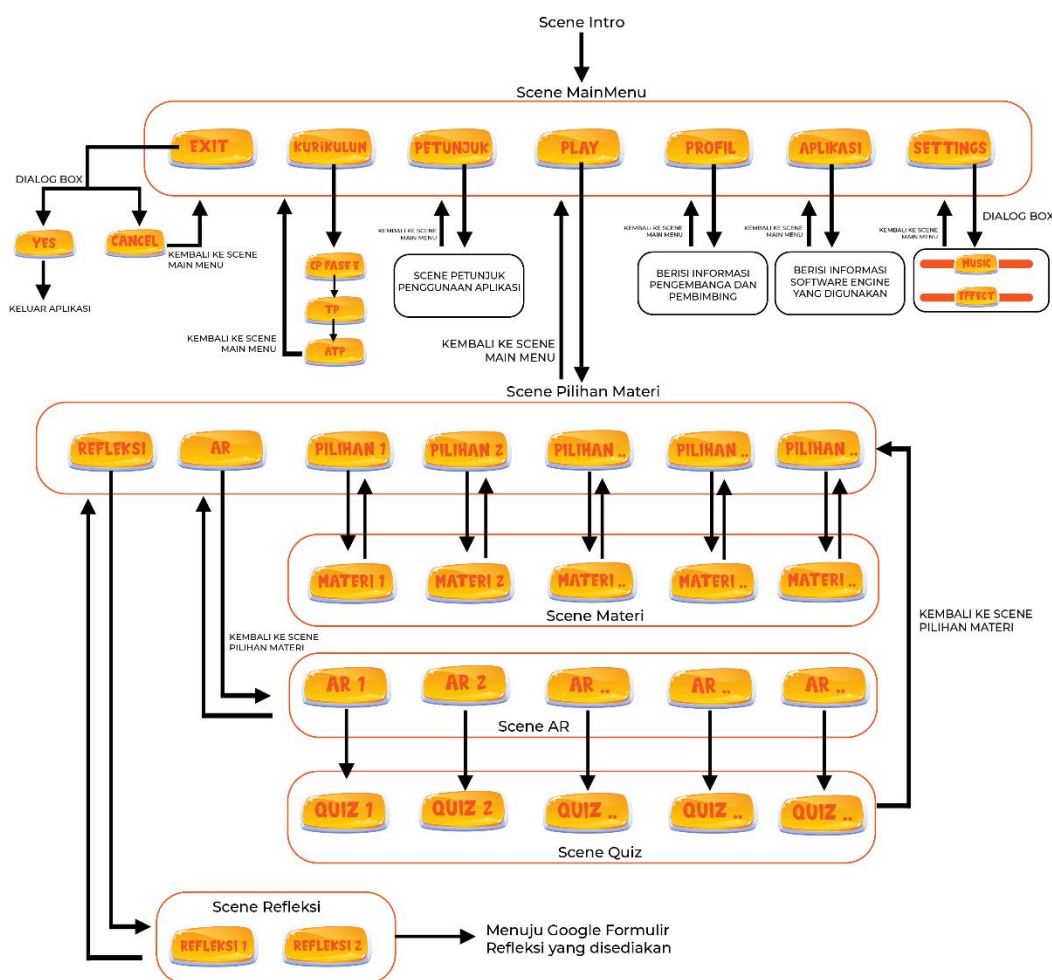
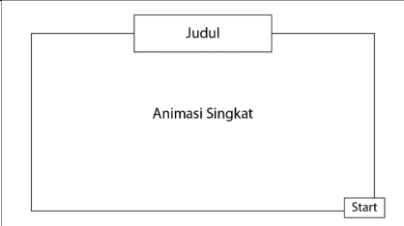
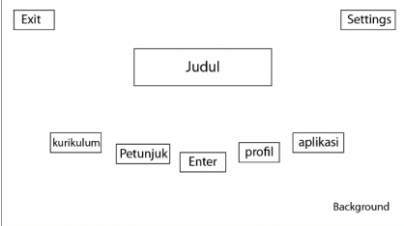

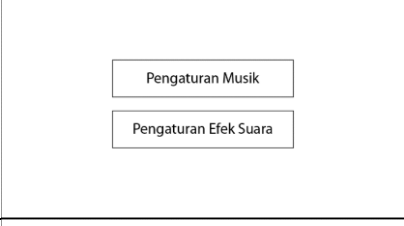
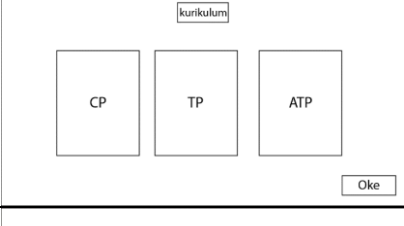
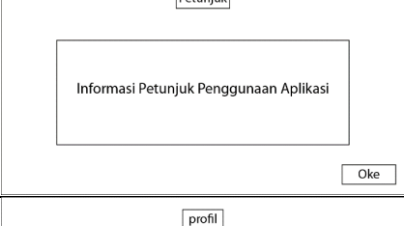
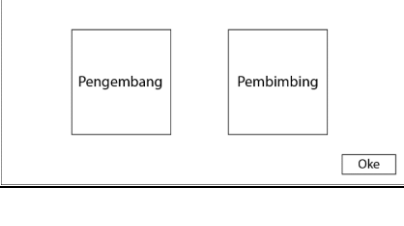
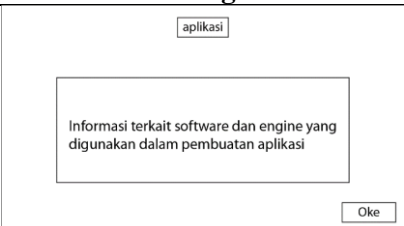
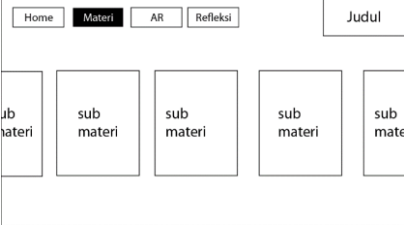
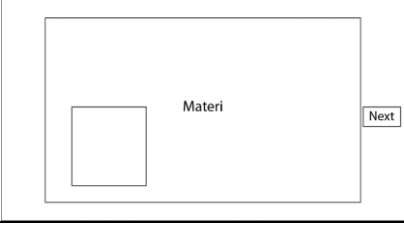
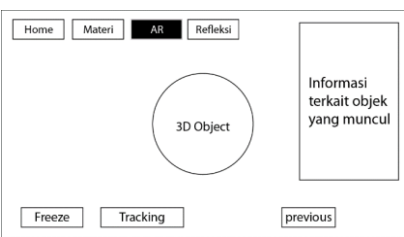
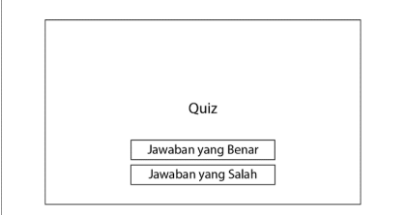





Figure 5. Application Activity Flowchart

Mobile application flowchart helps in efficiently planning, communicating, identifying issues, developing, testing and documenting mobile application workflows or processes. Besides the flowchart, in the initial plan an application storyboard design is carried out. application storyboards serve to visualize concepts, organize storylines, identify design needs, facilitate team collaboration, test user flows, as well as reference documents in mobile application development. The application storyboard is given on Table 1.

Table 1. The Application Storyboard

Page	Design	Description
Intro Scene		The application begins with a short animation regarding the material being taught, namely atomic theory and its constituent sub-particles. The start button will go to the main view
Main Menu		The background on the first page is designed by inputting five atomic models with a blurry appearance so that the buttons look more prominent. The main view contains several components, with the main component "enter" to continue in the material selection scene
Exit		The user will be asked for confirmation to exit the application. There is a "no" button to return to the main page, and a "yes" button to exit the application
Settings		Users can adjust the music volume and sound effects with the sliding button feature
Curriculum		The curriculum scene contains cp, tp, and atp along with an "ok" icon to return to the main page
Instructions		The instructions scene contains information on how to use the learning application along with the "OK" icon to return to the main page
Profile		The profile scene contains developer and supervisor information along with an "ok" icon to return to the main page



Page	Design	Description
About Application		The application scene contains information related to the software engine used in making learning applications along with the "oke" icon to return to the main page
Material Choice		Material selection scenes contain sub materials that can be selected by the user. There are also several buttons on the top left to show and select the required scene destination
Material		The material scene contains a brief description of the material displayed with animation on text and images related to the material
AR		Scene AR displays 3D objects according to the material being taught. The user will observe the object that appears to be able to answer the quiz in the next scene. Freeze button will help the user to observe the object by stopping the object from changing position. Button tracking helps users to bring up 3D Objects
Quiz		The quiz scene contains questions that must be answered by the user according to the type of quiz that appears (for example: multiple choice, true/false, filling in the blanks).
Right Answer		The correct answer will be given an appreciation with a picture that supports the happy atmosphere, and is equipped with an "okay" button to continue the quiz or end the quiz when the quiz ends
Wrong Answer		Wrong answers will be given unyielding words with pictures that support the spirit, and equipped with an "okay" button to continue the quiz or end the quiz when the quiz ends

Page	Design	Description
Reflection		The reflection scene contains reflection buttons for meetings 1 and 2 which take the user to the Google form regarding the use of the application

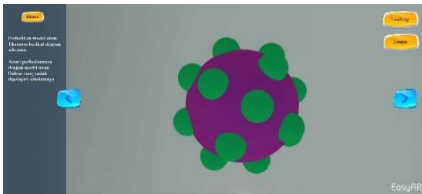

Self Evaluation

Self evaluation is carried out after realizing the designs needed to make integrated Augmented Reality application on the material for the development of atomic theory. Self-evaluation was carried out using the check-list method to see the completeness of prototype I. The application functions are designed in accordance with the results of analysis in preliminary research according to user needs, where in general applications there are home pages, student centered materials, quizzes, markerless AR pages, and reflections. The previous research, Supriono & Rozi (2018) and Rosma Aryani et al (2019) and stated that mobile application with Augmented Reality is successfully built, can run well from the aspect of functional suitability and stated students' interest in learning increased due to the learning application assisted by marker based Augmented Reality media. However the learning applications are not yet equipped with an interactive learning process in its application that guides students to find concepts. The use of Augmented Reality requires a physical marker. According to (Sung et al., 2016) markerless Augmented Reality system with deformable objects can overcome the weakness of traditional marker based augmented reality system with rigid object that are not suitable to apply to other various fields including education area. In addition, the application has not been equipped with reflection as a review of students' conditions during the learning process. Therefore, this research designed a learning application that was equipped with material that guided students to find the concept through quizzes and direct observation of 3D objects without the need for markers. In addition, the application is designed by providing reflection to students for each meeting in class. This application uses Plomp development model. In development research using the Plomp development model, self evaluation is carried out using a checklist instrument. The self evaluation result is given on Table 2.

Table 2. Self Evaluation Result

No	Page	Description	Display	Conclusion
1	Cover Page	Cover page is successfully displayed with the button on the left bottom and move to the main menu page		Succeed
2	Main Menu Page	Main menu page is successfully displayed with the menus, settings, and exit button. Selected button displays the right page as programmed		Succeed

No	Page	Description	Display	Conclusion
3	Curriculum Page	Curriculum page is successfully displayed including CP, TP, and ATP. Okay button closes curriculum page and displays main menu page		Succeed
4	Instructions page	Instructions page is successfully displayed. Okay button closes the page and displays main menu page		Succeed
5	Profile Page	Profile page is successfully displayed. Okay button closes the page and displays main menu page		Succeed
6	About Application Page	About application page is successfully displayed. Okay button closes the page and displays main menu page		Succeed
7	Material Selection Page	The materials page is successfully displayed with the horizontal view		Succeed
8	Learning Material	Learning material is successfully displayed with the audio and animation figures		Succeed
9	Quiz Page	Quiz page is successfully displayed with the option buttons.		Succeed
10	Quiz Feedback	Quiz feedback is successfully displayed equipped with the button to review the learning material		Succeed

No	Page	Description	Display	Conclusion
11	AR Page	3D object is successfully displayed with the future to zoom the object, replace the object anywhere, and rotate the object.		Succeed
12	Reflection	Reflection page is successfully displayed		Succeed

The designed application complements the design of existing research by providing a main menu which is equipped with several sub menus, namely curriculum, instructions, profiles, about the application, and play to continue on the material selection page. On the material selection page, there are several sub-materials that are displayed with a horizontal scroll view. The material displayed is oriented towards student processes where students find their own concepts by carrying out each programmed process complete with quizzes and observations through 3D objects in Augmented Reality without the need for markers. In addition, the application is also equipped with a reflection page for each meeting. So the result is that the application with Markerless Augmented Reality is successfully executed according to the programmed function and is expected to be continued to the next prototype.

CONCLUSION

Based on preliminary research data and the prototyping phase, it can be concluded that the design of learning applications using the Plomp development model which produces prototype II that has been successfully run as expected according to the design based on the results of analysis in preliminary research. This application is a solution as learning media that can help users to understand more about evolution of atomic theory through finding the concepts with the help of markerless Augmented Reality and quiz on every sub material.

RECOMMENDATION

Recommendation based on the results of reasearch, it is hoped that this application prototype can be continued to generate interactive learning application using markerless Augmented Reality on evolution of atomic theory material that can be used at schools to support chemistry learning.

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