Development of Marker-Augmented Reality Integration (M-ARI) Based Teaching Module as a Support for *Merdeka Belajar* Curriculum in Physics Education

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Abstract. Research has been conducted on developing a Marker-Augmented Reality Integration (M-ARI) based teaching module. This research includes a physics teaching module aligned with the *Merdeka Belajar* curriculum. The expected information from this research pertains to; (1) The process of developing the M-ARI-based teaching module; and (2) the characteristics of the M-ARI-based teaching module that are suitable for use. The development design used is design thinking, consisting of five stages: empathize, define, ideate, prototype, and test. This study was conducted at SMAN 4 Makassar with 85 student participants. The Empathize stage of this re-search resulted in an understanding of the problem area, which is the abstract nature of atomic model materials. The Define stage resulted in supportive media that can visualise each atomic model in a 3D, engaging manner, easy to use, and accessible anywhere. The solution design in the Ideate stage yielded four main features in the application: navigation feature, atomic model visualization feature, flexibility in observing atomic models feature, and application system feature. The prototype feature design of the application used Unity version 2020.3.30f1 and an augmented reality system from the Vuforia Engine platform. Based on the assessment by two experts using the Gregory test, the feasibility testing results of the M-ARI-based teaching mod-ule indicated content feasibility with a score of $1.00 \geq 0.75$ and media feasibility with a score of $0.76 \geq 0.75$. Based on the feasibility testing results and the consensus of the two experts, the M-ARI-based teaching module is deemed suitable for use in the learning process.

Keywords: atomic models, Marker Augmented Reality Integration (M-ARI), Merdeka Belajar curriculum.

1 Introduction

The 21st century learning framework requires incorporating elements of technology into the learning process that focuses on Creativity, Critical Thinking, Communication, Colaboration and student-centered learning systems (Student Centred Learning). In line with the renewal of the learning system, the development of digitalization in Indonesia is intensified to support the learning system. The growth in internet use was

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followed by the growth of the population using mobile phones in 2020 reaching 62.84 percent [1]. Based on these data, the use of telecommunication media and 21st cen-tury learning support platforms has become quite crowded research, especially in the field of educational technology in the last five years.

Along with the demands of the times, three-dimensional based media has become one of the innovations in learning. Especially in physics learning materials. This me-dia is intended to visualize an event so that it is easy to understand. One of them is the use of Marker Augmented Reality Integration (M-ARI) technology. Marker Aug-mented Reality Integration (M-ARI) is "a technology that combines two-dimensional and/or three-dimensional virtual objects into a real environment and then projects those virtual objects in real-time [2]. Augmented Reality (AR) only adds to or complements reality. M-ARI is an effort to combine the real world and the vir-tual world created through a computer so that the boundary between the two be-comes very thin [3]. The advantage of AR is that it can be implemented through a smartphone application by producing more interesting learning media [4].

Research shows that it shows that 78.2% of students find it difficult to understand physics concepts because learning is only delivered with textbooks and doing prob-lems that contain formulas only. [5] While some physical materials require deep vis-ualization, not all physical phenomena can be directly observed. By seeing the potential of AR that can visualize in three-dimensional form, the development of physics learn-ing media, especially physics materials that require deep visualization, can be devel-oped. Abstract physics material becomes material that is difficult for students to under-stand and it is easy for misconceptions to occur in the material [6]. One of the abstract physical materials is the atomic model material [7]. The difficulty of students in atomic model material is understanding the characteristics and describ-ing each atomic model [8]. With this problem, M-ARI is one solution that can im-prove the quality of the learning process. This is based on the results of research that reveals that the use of AR learning media has a positive effect on the teaching and learning process [9]. AR media allows students to use engaging learning facilities and an authentic learning environ-ment [10]. AR learning media shows an increase in students' knowledge abilities in the field of science because of the advantages of Augmented Reality (AR) in visualizing information conveyed [11].

The type of AR developed in this study is image-based by scanning two-dimen-sional images. Berikut gambar dari modul ajar berbasis M-ARI untuk materi model atom.

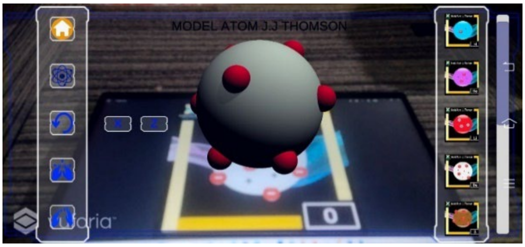

Fig. 1. visualisasi 3D model atom J.J Thomson

In building creative and effective ideas by focusing on human needs can apply the designer's approach and methods for the development of innovation. Institute of Design at Stanford in bootleg design thinking, dividing the design stages into five, namely are empathize, define, ideate, prototype, dan test [13]. The design thinking process is not linear, here is a flow diagram of the design thinking process proposed by the Stanford D. School in bootleg design thinking as follows.

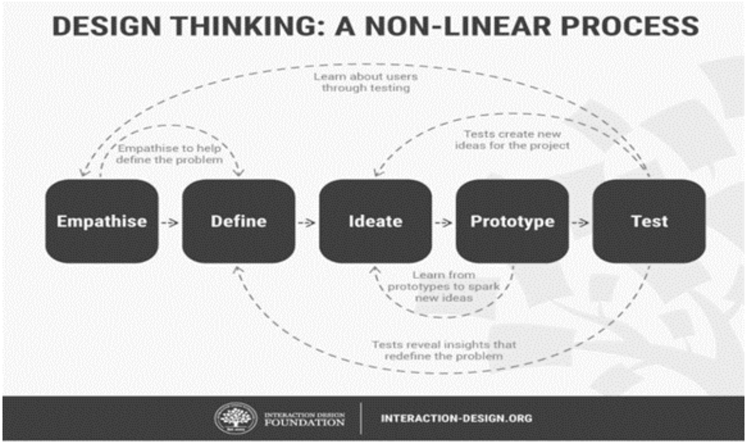

Fig. 2. Design thinking scheme

Based on the problems stated above and the advantages of AR technology, a study was conducted that aimed to determine the feasibility of Marker-Augmented Reality Integration (M-ARI)-based learning media for atomic model materials.

2 Method

This research is a type of Research and Development (R&D) research by adapting the Design Thinking model. According to the Institute of Design at Stanford in boot-leg design thinking, there are five stages in design thinking namely empathize, define, ideate, prototype, and test (Doorley et al., 2018). [14]

The population in this study was all students of SMAN 4 Makassar Class XII Science which amounted to 85 students. With the characteristics of the population has already used and made applications with the addition of AR technology. The sample in this study was students of class XII IPA SMAN 4 Makassar with a total of 55. The sampling technique used is non-probabilty sampling with a purposive sampling model. Purposive sampling is a sampling technique based on research objectives [15]. Sample selection is based on criteria related to the purpose of research. This research was conducted in five stages, namely empathize, define, ideate, proto-type, and test. The following is the scheme of the stages of research as follows.

At the empathize stage, a process is carried out in understanding the problem and the needs needed to solve the problem based on the researcher's point of view. In this process, all observation data using the worksheet question design are analyzed using the SWOT analysis method. This method is used to reframe all problems and concerns of students in the atomic model learning process.

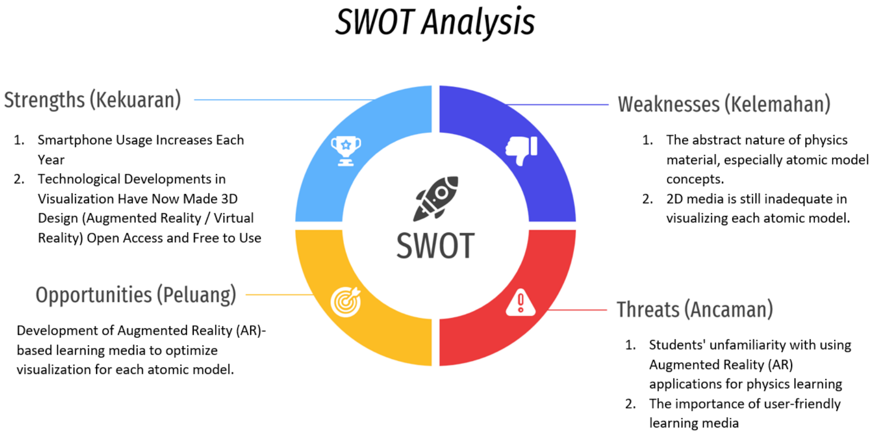

Fig. 3. SWOT Analysis Scheme

Based on the results of SWOT analysis, user research is carried out to understand and confirm problems and solutions made by researchers using observation sheets in the form of research plans. The research plan includes challenge design; researcher profile; determination of users and stakeholders; Sources; research plan; and Interview guide. The results of the research plan will confirm in more detail and systematically the problems and solutions of researchers based on the point of view of users and stakeholders that will be published at the next stage.

At the define stage, the process of defining, managing, and summarizing each data from user research is carried out to find out the specifics of the problem from the empathize stage. The process of redefining problems and solutions based on user and stakeholder points of view is contained in personas, empathy maps, and user journeys. The results of this empathy map are used to remap every problem and solution from students and physics teachers so that all problems felt by students can be clearly defined and the solutions provided by researchers can be solutions desired by students and teachers.

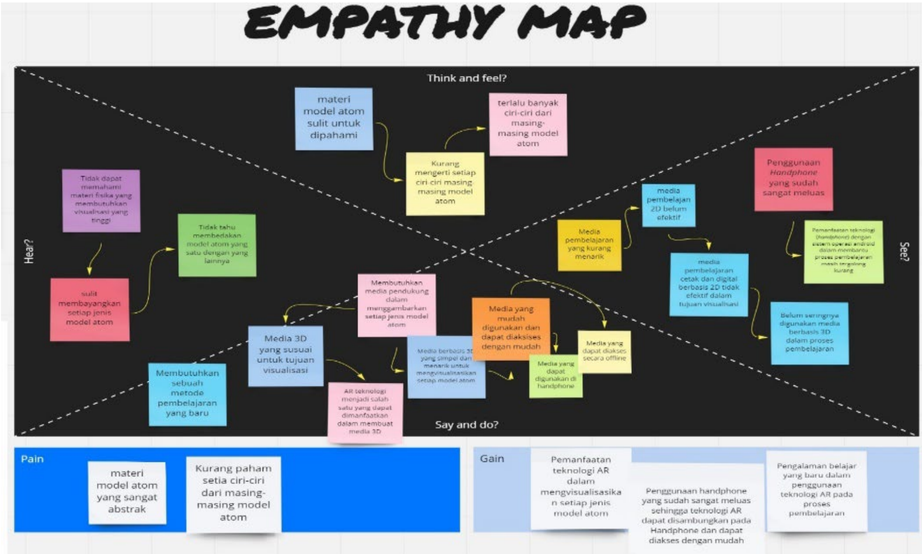

Fig. 4. Empathy map

The results from this empathy map are used to remap each problem and solution from the students and physics teachers, allowing all the problems felt by the students to be clearly defined, and the solutions provided by the researchers to be solutions that are desired by both the students and the teachers. The outcome from the empathy map indicates that the students need a tool that can help them illustrate each type of atomic model in 3D visualization and can be accessed anytime and anywhere.

At the ideate stage, the process of collecting ideas is carried out in solving problems faced by users (students) based on the results of the define stage. This Idea collection is carried out using the brainstorming method, where ideas are gathered from each problem faced by users that have previously been mapped in the form of an empathy map and user journey. This idea collection aims to determine the name and features of the designed product. The outcome of brainstorming resulted in the name of the product to be designed, PyLo-AR (Physics Learning of Augmented Reality), along with a table of features for the PyLo-AR application..

Table 1. Features in the PyLo-AR application

No	Feature name	Feature usability
		Navigation Feature
1	Main Menu	As the main portal in the PyLo-AR application
2	Play	As the entry point to view all navigation features in the PyLo-AR application
3	Marker	As a place to download all markers from the PyLo-AR application
4	Tutorial	Helps users to use the PyLo-AR application for the first time

5	About us	Provides information to users about the developers and the purpose of the PyLo-AR application
6	Q&A	Provides information to users about solutions to some critical points in the use of the PyLo-AR application
7	Information	Provides users with the opportunity to ask developers questions if system errors occur outside of the Q&A
8	Home	Makes it easier for users to return to the main menu
9	Exit	To exit the PyLo-AR application
		Main Feature
10	Dalton Atomic Model Visualisation	Provides real-time 3D visualization on the user's smartphone with Marker-based Augmented Reality technology
11	J.J Thomson Atomic Model Visualisation	
12	Rutherford Atomic Model Visualisation	
13	Bohr Atomic Model Visualisation	
		3D Observation Flexibility Feature
14	Selection of Atomic Model	Eases user in selecting the atomic model when observing a different 3D atomic model
15	Selection of Elements and Interaction in Each Atomic Model	Eases user in selecting and observing 3D objects of each element and the interactions in every atomic model
16	Rotation	Rotates the 3D object of each atomic model, allowing users to observe the 3D object from all angles
17	Zoom In	Zooms in on the 3D object of each atomic model so that users can observe the object in greater detail
18	Zoom Out	Zooms out on the 3D object of each atomic model to give users a wider view of the object
		Application System Feature
19	Scrolling	Eases user in selecting each navigation, main, and flexibility feature in the PyLo-AR application
20	Vuforia Augmented Reality	Synchronizes the marker system on 3D objects for the application of Marker-based Augmented Reality technology
21	SDK (Software Development Kit) Android	Translates the designed system to be compatible with the Android operating system

At the prototype stage, the process of designing the User Interface (UI) and building the PyLo-AR application system is carried out. In making designs, solution design techniques are used that produce sketch data, guideline designs, mockups and screenflows based on feature data.

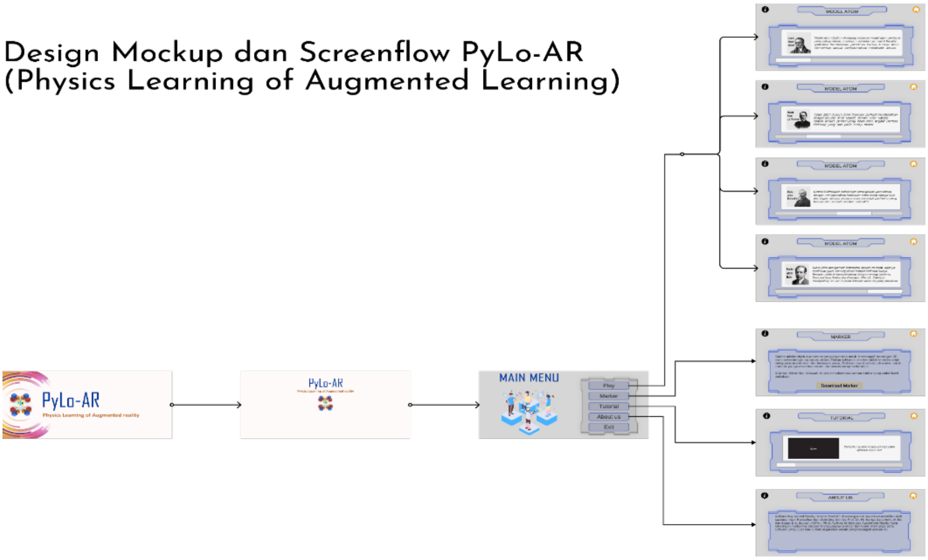

Fig. 5. Design Mockup and Screenflow PyLo-AR

The PyLo-AR application sketch depicts the initial look of the User Interface (UI) for the PyLo-AR application. Figure 5 contains 11 main scenes/layers based on the interaction map design, summarizing all the features of the PyLo-AR application. Based on this sketch design, the User Interface (UI) design composition is created with a design guideline that includes colors, font styles, and icon symbols used in designing the UI for the PyLo-AR application. The design mockup aligns with the screenflow, representing the usage flow of the PyLo-AR application. The complete design mockup can be viewed at the following link: https://bit.ly/MockupPyLo-AR.

The development of the PyLo-AR application system was built using CorelDraw version 2021, Blender version 3.0, and Unity version 2020.3.30f1. CorelDraw is used to create the marker design for each atomic model.

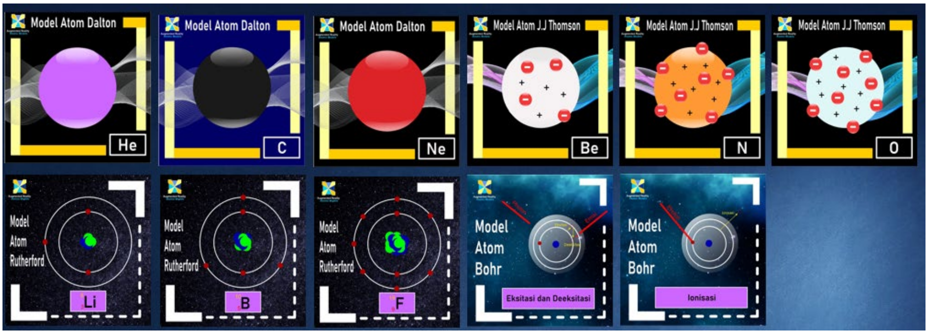

Fig 6. Marker of PyLo-AR Application

This marker design is useful for calling 3D objects in real-time directly on top of the marker. The markers are uploaded to the Vuforia platform system as the marker database for PyLo-AR.

The final stage, Test, is the phase for trialing the PyLo-AR application. This stage aims to assess the feasibility of the PyLo-AR application. This trial measures the feasibility of the PyLo-AR application from a theoretical perspective by evaluating the content of the atomic models included and the quality of the media in the PyLo-AR application using a consensus technique with Gregory's analysis.

3 Result and Discussion

3.1 Result

The results of research related to the feasibility (valid) of products used to test the validity of the content can be carried out qualitatively and quantitatively by several experts. PyLo-AR application testing was carried out to determine the feasibility of the PyLo-AR application theoretically with the method of understanding of two Gregory analysis experts. This feasibility measurement is done by validating the content and media contained in the PyLo-AR application. The results of content validation (content) and media validation were given to two content experts (content) to evaluate the content of the atomic model of the PyLo-AR application and two media experts to evaluate the media quality of the PyLo-AR application. The results of Gregory's internal costitution coefficient analysis for content and media are $1.00 \geq 0.75$ and $0.76 \geq 0.75$ or the content and media contained in the PyLo-AR application can be used in the learning process [16]. Based on the results of feasibility testing of understanding between two experts who stated that the PyLo-AR application can be used in the learning process.

3.2 Discussion

Pylo-AR is the end product of this research. PyLo-AR is an application Based Markerkasi Augmented Reality android operating system so that it can be used on android smartphones. PyLo-AR is designed with design thinking method. Based on the objectives of this study, testing was carried out on the PyLo-AR application to find out the feasibility of PyLo-AR applications for atomic model materials and user-friendly propertiesof PyLo-AR applications. Feasibility testing is carried out theoretically and empirically. Feasibility testing is theoretically used content and media validation instruments with argregory techniques to measure the feasibility of content (content) and media con-tained in the PyLo-AR application [17]. The results of this test obtained a con-tent validation score of 1.00≥ 0.75 which means that the atomic model con-tent contained in the PyLo-AR application is very compatible with atomic model theory and is very feasible to be used in assisting the learning process. Meanwhile, for media validation there are some invalid items and some media improvement suggestions contained in the PyLo-AR application, these improvements include adding flexibility features in observing 3D objects from each atomic model, tutorial features that are easier to understand, and further testing is needed related to the use of PyLo-AR applications on all types of mobile phones with the Android operating system. However, overall media validation testing obtained a score of 0.76 ≥ 0.75 which means that the media contained in the PyLo-AR application can be used in assisting the learning process with slight improvements [18].Based on the results of this theoretical feasibility test, several improvements were made to the features of the PyLo-AR application before an empirical feasibility study was carried out The PyLo-AR application becomes a suitable application for atomic model materials based on the results of content validation tests and media validation using ex-pert understanding analysis through gracing tests. Gregory's internal coefficient values for content and media are 1.00≥ 0.75 and 0.76≥ 0.75 or the atomic and media model content contained in the PyLo-AR application is valid and can be used in the learning process.

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