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Learning innovation: Development of static electricity teaching module based on marker augmented reality with design thinking method

Nazirah Nasri, Khaeruddin, Imam Ramadhan, Mutahharah Hasyim & Eko Hadi Sujiono
Faculty of Mathematics and Natural Sciences, Makassar State University, Jl. Daeng Tata, Makassar, Indonesia

Corresponding author: nazirahnnk97@gmail.com

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ABSTRACT

This research aims to develop and evaluate a static electricity teaching module based on Marker Augmented Reality (MAR) called PyLo-AR using a Design Thinking approach. The module is designed to help learners understand static electricity concepts through visualization. The research assesses content and system validity, module effectiveness, and feedback from students regarding the teaching module. Validation results indicate that PyLo-AR has excellent content validity and good system validity. Effectiveness testing shows that the success rate of students using the PyLo-AR application is categorized as high, with a percentage score of 95.11%. SUS measurement results show an average score of 53 for Grade X and an average score of 70 for Grade XII. The study results indicate that the marker-based augmented reality teaching module, PyLo-AR, is valid in terms of content and system and has a relatively good acceptance level from users. This suggests that PyLo-AR can be an effective alternative in the physics learning process.

Keywords: Learning module, static electricity, augmented reality, design thinking

INTRODUCTION

The development of information and communication technology has had a significant impact in various aspects of life, including education. One technology that is increasingly popular and attracts attention is augmented reality (AR). AR is a technology that projects virtual objects into a real environment in real time (Cuhanazriansyah et al., 2023). The ability of AR technology to create more real visualizations can be a solution to provide a deeper understanding of abstract physics concepts.

Static electricity is one of the materials in physics that is often considered abstract and difficult for students to understand. This is due to the invisible nature of static electricity and difficult to visualize concretely. As a result, many students have difficulty in understanding the basic concepts of static electricity such as electric charge, Coulomb force, and electric field. In addition, conventional learning methods such as lectures and textbooks tend to make students feel bored and less motivated, as emphasized by Socrates and Mufit (2022), the lack of innovation in learning affects the ability of students to understand the material.

Teaching modules with augmented reality (AR) integration are learning innovations that enable independent and guided learning (Prastowo, 2011). Modules are designed with a structured series of learning activities to help learners achieve learning objectives (Sihotang, 2020). According to Sholeh et al. (2021) and Bakri et al. (2018), the use of augmented reality technology in learning can provide a more real learning experience for students and a more detailed explanation through the presentation of material in 3D. Cuhanazriansyah et al. and Zakaria et al. (2023) revealed that augmented reality-based learning media is effective for visualizing abstract concepts and worth using as a new media in physics learning. This allows learners to more easily understand difficult concepts and build a deeper understanding.

The literature review shows that the use of AR in learning has shown positive results. Some previous studies have successfully improved students' learning achievement in various subjects, including physics. However, research on marker-based augmented reality (AR) teaching modules in static electricity learning is still relatively limited. Therefore, this research is expected to contribute to the development of technology-based learning innovations in physics.

Specifically, this study will answer the following research questions: 1) how is the validity of the marker augmented reality (AR) based teaching module in terms of content and system; 2) how is the effectiveness of the marker augmented reality based teaching module in terms of the system; how do students respond to the marker augmented reality based teaching module in static electricity learning? Thus, this research is expected to be a reference for educators and learning media developers in an effort to improve the quality of physics learning, especially static electricity material.

LITERATURE REVIEW

Teaching module

Modules are self-learning guides designed to help learners achieve learning objectives effectively (Prastowo, 2011). According to Sihotang (2020), teaching modules are complete packages containing subject matter that is arranged systematically and easy to understand, so that students can learn independently. In addition, Agustinaningsih (2023) emphasized that teaching modules can train students to be more independent and responsible in their learning process. The development of teaching modules that are suitable for the needs and characteristics of students is very important to create interesting and meaningful learning (Putri, 2016). Teaching modules based on the Merdeka Curriculum, as explained by Maulida (2022), generally consist of three main parts, namely general information, core material, and attachments. This teaching module is designed to be a complete and effective learning guide helping learners achieve learning objectives optimally.

Augmented reality (AR)-based teaching modules are learning innovations that allow learners to see and interact with objects or information that are not visible in the real world (Khairunnisa et al., 2023). AR technology is able to transform abstract concepts into more real visualizations, thus stimulating students' critical thinking skills (Cuhanazriansyah et al., 2023; Chaeranti et al., 2018). Integrating AR in teaching modules also provides flexibility in learning, because students can learn anytime and anywhere (Surani, 2019). AR is also proven to increase the effectiveness of the teaching and learning process (Ramadani et al., 2022).

Augmented reality

Augmented Reality (AR) is a technology that combines the real world with digital elements in real-time (Cuhanazriansyah et al., 2023). This technology is very useful in learning, especially for visualizing abstract concepts. For example, AR can be used to display three-dimensional models of objects that are difficult to imagine, through everyday devices such as smart phones (Wijaya, 2020), so that learners can more easily understand and remember the information (Usada, 2018).

This research uses the marker-based method to develop augmented reality (AR) based teaching modules. This method works by recognizing predefined markers. When the camera detects this marker, the phone will display a pre-programmed three-dimensional object in a location that matches the position of the marker in the real world (Naqiyah et al., 2020; Satria & Prihandoko, 2018). In other words, the marker acts as a marker for the computer to place virtual objects in the real world.

Design thinking

Design thinking is an approach that puts humans at the center of the innovation process. It combines a deep understanding of user needs with the potential of technology to create innovative solutions (Dam & Siang, 2021). In other words, design thinking is the process of finding the right solutions to problems faced by humans, by always involving users in every stage of development (Hussein, 2018). This process is iterative, meaning that it can be repeated and improved continuously (Dam & Siang, 2021).

Design thinking is a systematic approach to solving problems by actively involving users. The process includes five stages, namely: empathizing with users, clearly defining the problem, generating a range of creative ideas, creating an initial model of the solution, and testing the solution. The ultimate

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goal of design thinking is to create solutions that are not only innovative, but also relevant to user needs. This method is not only useful for designers, but can also be applied in various fields (Ayu & Wijaya, 2023; Dam & Siang, 2023).

METHODOLOGY

This research is a development research that aims to develop innovative learning products, namely marker-based augmented reality (AR) teaching modules for static electricity materials. The development process adopts the Design Thinking model introduced by Stanford's d. school which consists of 5 phases, namely: empathize (understand users), define (formulate problems), ideate (generate ideas), prototype (create initial models), and test (evaluate) (Dam, & Siang, 2021). This model was chosen because it allows for user-centered and iterative product development.

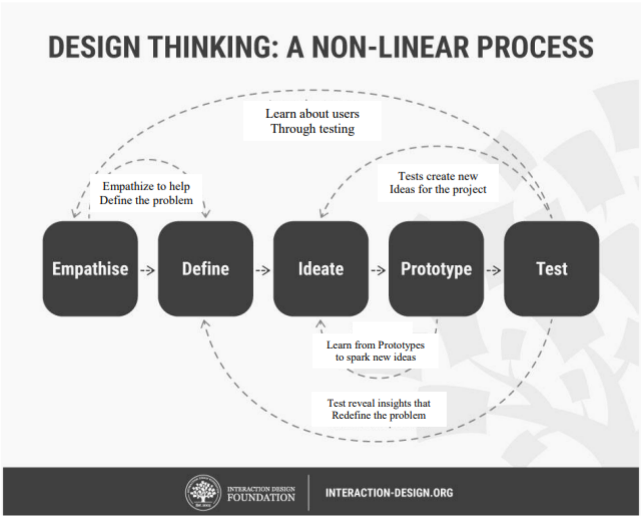

Figure 1. Design Thinking Flow Chart

To ensure the success of the development and testing of teaching modules, this study involved students from SMA Negeri 2 Makassar as research subjects. The selection of subjects was carried out by purposive sampling by considering certain criteria, namely: students of SMA Negeri 2 Makassar, having a smartphone with Android 6.0 operating system or higher, and willing to use PyLo-AR application. These criteria were chosen to ensure the smooth implementation of the research and the relevance of the data obtained.

The empathize stage is an in-depth process to understand the problems and needs of students in learning abstract physics material. Through observations using the design question worksheet, the main obstacle was found to be limited understanding of concepts due to the lack of effective 2D learning media in visualizing abstract concepts such as electric fields and Coulomb forces. SWOT analysis confirmed that the development of marker-based augmented reality (AR) teaching modules has the potential to be an effective solution. AR technology can present a more dynamic and interactive visualization, so it is expected to improve students' concept understanding. To validate the initial findings of the problem from the user's perspective, further user research was conducted using a research plan involving students. The data obtained from the research plan was used to confirm the problems and solutions that had been identified, and provide more specific input for the define stage.

The define stage is a stage to process the data obtained from the empathize stage into a deeper understanding of physics learning problems. Through in-depth analysis of the results of observations and interviews, the problems and needs of users (learners) are specifically defined. To visualize the problems and solutions, three main tools were used: persona, empathy map, and user journey. Persona depicts the ideal profile of learners, including their needs, motivations, and challenges. Empathy map visually presents learners' perspectives on physics learning, including what they think, feel, see and do. User journey describes the flow of learners' interaction with the AR learning module, from before, during, to after use.

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The ideate stage involves brainstorming sessions to generate innovative ideas to overcome the identified learning challenges. The results of this brainstorming become the basis for designing the AR module user interface. The prototype development process is carried out using Blender software to create 3D models, Unity to integrate 3D models with AR markers, and Canva to design markers. The marker that has been designed is then uploaded to the Vuforia platform to be used as a trigger for the display of 3D objects to appear. The following is the initial rendering of the PyLo-AR application for the Android operating system.

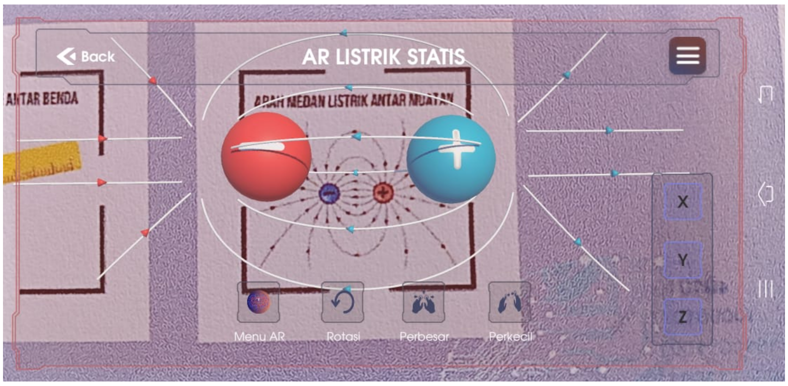

Figure 2. Initial Rendering of PyLo-AR 3D App

The testing stage aims to assess content and system validity, product effectiveness, and user satisfaction. Measurement of validity through the analysis of the agreement of two Gregory formula experts to ensure that the material presented in the application is accurate and relevant to the curriculum and the system in the application according to system operating standards. Effectiveness measurement was conducted using the tasking method to measure the success of the features designed in the teaching module. Measurement of user satisfaction is carried out using the System Usability Scale (SUS) to collect data on user perceptions of ease of use, usability, and overall satisfaction. The data collection techniques used include: 1) observation, which is directly observing the learning process to see the behavior and difficulties experienced, 2) interview, which is conducting in-depth interviews with students to explore their opinions and input, 3) survey, which is collecting quantitative data through questionnaires, to assess the validity of the teaching module, measure the effectiveness of the PyLo-AR application, including the use of the SUS scale to measure ease of use, 4) triangulation, which is combining data from various sources to obtain a more comprehensive and accurate understanding.

RESULT AND DISCUSSION

Validity testing

After the product was designed, the validity of the content and system contained in the PyLo-AR application was tested. The test was conducted using content and system validation instruments with Gregory's two-expert agreement analysis technique to measure the feasibility of the content and system contained in the PyLo-AR application. The results of the content validity test showed a score of 1.00, exceeding the minimum threshold of the internal consistency coefficient of 0.75. This indicates that the static electricity content in the PyLo-AR application is very accurate and relevant to the learning material. Meanwhile, the system validity test results showed a score of 0.76, close to the minimum threshold of 0.75. This value indicates that the system contained in the PyLo-AR application can be used in assisting the learning process with some improvements that need to be made to the system (Privitera, 2015).

Effectiveness and efficiency testing

To measure the effectiveness of the PyLo-AR application, testing was conducted using the tasking method. Learners were given tasks designed to test the quality of the product in terms of user-friendliness in learning and operating the PyLo-AR application. The percentage of successful tasks done by learners is shown in the following diagram:

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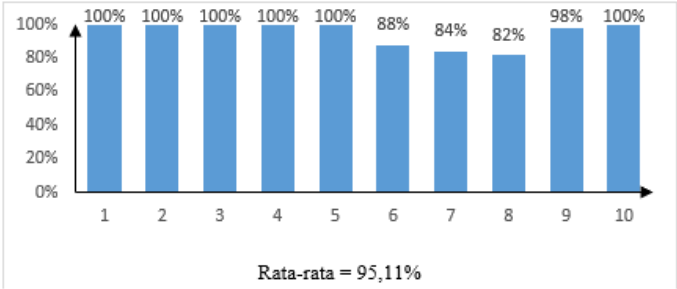

Figure 3. Percentage of Task Completion Effectiveness

Figure 3 shows the effectiveness graph for each task. There are 6 tasks that have the highest effectiveness value, namely in tasks 1, 2, 3, 4, 5, and 10 with a value of 100%, which means that 49 participants successfully completed the task in accordance with the objectives to be achieved. The tasks are related to creating a username and password and being able to operate the features in the application according to their functions. In addition, there are also several tasks that cannot be completed by students, namely tasks number 6,7,8, and 9. These tasks are related to the appearance of 3D objects and cannot be completed because some features cannot function on the students' devices.

Based on the calculation results with the completion rate technique, the application effectiveness value is 95.11%. According to the effectiveness criteria referred to, the system can be declared effective if the value of the effectiveness variable is above 75%. So it can be concluded that the PyLo-AR application is very effective in terms of the system, which means that the system in the application can run well and users can operate the application (Wahyuningrum, 2021).

User response measurement

After effectiveness testing, a survey measuring user response using the System Usability Scale (SUS) was conducted to 49 respondents (class X and XII). The analysis results showed an average SUS score of 53 from class X respondents and 70 from class XII respondents. In accordance with the guidelines proposed by Brooke (1995), SUS evaluation results can be analyzed based on three main aspects, namely acceptability ranges, grade scale and adjective ratings as follows:

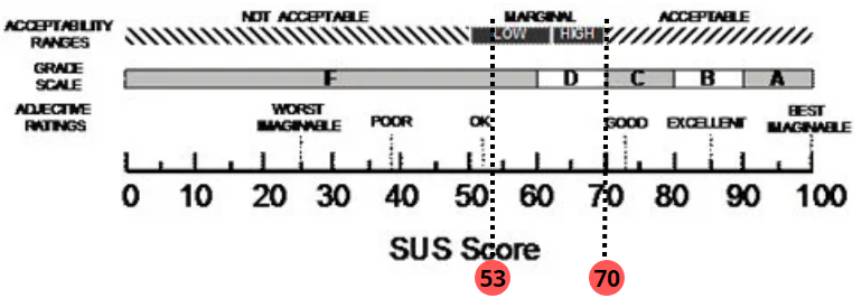

Figure 4. System Usability Scale (SUS) Assessment

The interpretation of SUS scores in Figure 4 shows that class X is in the acceptability ranges = "marginal", grade scale = "D", and adjective rating = "Ok". While class XII is in the acceptability ranges = "marginal", grade scale = "C", and adjective rating = "Ok". Acceptability ranges are an aspect in determining the level of application acceptance, in this case class X and XII respondents both show an acceptance level that is included in the marginal category, which means that the application is acceptable (Aisyah et al., 2021). Grade scale is an aspect in determining the level of application quality, in this case there are differences in the interpretation of SUS scores from class X and XII respondents. Grade X respondents determine the level of application quality at grade "D" while grade XII respondents determine the level of application quality at grade "C" which means the application quality is quite good (Sukma et al., 2023). Adjective rating is an aspect in determining the level of application usability, in this case class X and XII respondents both gave the category "Ok" which means that according to the user the application can be used (Pramudya & Raharja, 2022).

CONCLUSION

The results showed that the marker-based augmented reality teaching module with the name PyLo-AR was declared valid in terms of content and system, and had a fairly good level of acceptance from users. This shows that PyLo-AR can be an effective alternative in the physics learning process.

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