Designing prototype model of virtual geometry in mathematics learning

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Abstract. This study aims to design and to see the effectiveness of virtual geometry (VirGO) mobile application in learning mathematics based on Augmented Reality (AR). To create a virtual geometry application, the writer uses the three stages prototype method, making an AR software application using Unity3D, the process of modelling with Blender, and using Vuforia to develop augmented reality and marker. The experiment involves one hundred and twenty students in three junior high schools in Padang. The results of the study show that VirGO based on augmented reality has three advantages namely (1) the availability to display the detail objects and learning material realistically, (2) its interactivity supported by cutting-edge and powerful videos, images and animations features, and (3) increasing students' interest in learning mathematics and reducing boredom. The results of this study have proved that learning mathematics will be interesting and more memorable if the teacher has the will and creativity in making various learning media.
Keywords: augmented reality, mathematics learning, mobile application, virtual geometry, Vuforia

1. Introduction

Mathematics is a crucial subject should be studied by each student at every level of school in Indonesia including elementary, junior and senior high schools. However, some previous studies found that mathematics is one of the less interesting subjects for students [1]. Among the causes of the low interest in mathematics learning is most of the mathematics teachers still use conventional media in learning [2]. In the context of learning, the media is one of the most important instruments and cannot be separated from the teacher, because it will make learning be more memorable than the teacher only teaching in a conservative way such as lecturing (teacher-centred learning), taking notes or the teacher only explains the subject matter while students just sit, listen and keep quiet [3].

In general, media is a tool used by teachers in the classroom when the learning process occurred to stimulate the students' thoughts, feelings, attention and abilities or skills to achieve the desired learning process [4]. In mathematics learning, the role of media in achieving good learning process is equally important. According to some previous research results, it has been proven that the utilization of digital technologies such as e-learning, websites in mathematics learning is very significantly influential on student learning outcomes [4,5].

The development of mobile technology in mathematics learning media has been designed in various forms of learning applications such as virtual classes based on augmented reality [6]. Android-based

learning software has at least been able to change students' perceptions about learning mathematics which is considered difficult and boring. but through various media and applications, mathematics can be easily learned and even fun [7]. This means that the use of technology-based learning innovations by making students as learning centres has been able to influence learning outcomes, and can even change students' perceptions of mathematics.

Related to the issue of using technology in learning mathematics, the author explains that teachers' competence and creativity are highly required to be willing and able to actively use technology. If the teacher still sticks to the principles and conservative ways of delivering the subject matter, it will result in poor achievement in learning outcomes. According to Fry, Ketteridge, & Marshall, instructional media have a very important role in delivering a message, the media also functions as a mediator of the learning process between students and learning material [8,9]. In principle, students tend to be interested in the subject matter should teachers use teaching aids as learning media [10,11].

Associated with the problem of learning mathematics as the issue that the author revealed in this article, in various previous articles it was found that in reality most teachers still tend to be focused on completing the syllabus and choosing textbooks as learning media[11]. As a result, the learning process runs rigidly, less challenging, because the teacher considers students only a group of people who can only be quiet when receiving material in the learning process [12]. Yet according to the author, the mathematics learning process actually places more emphasis on reasoning activities, not from experimental results or observational results. It is precisely mathematics formed by human thoughts, which are related to ideas, processes, and reasoning. So ideally learning mathematics must involve various elements such as teachers, students, mathematics and its characteristics, as well as the learning situation that takes place [13,14].

To reach the advanced stage in mathematics, students need to learn a lot of material, but in this article, the author only focuses on discussing one aspect of mathematics subject matter, namely geometry. The choice of geometry material is based on the majority of students who consider the material to have been studied and understood [15]. Based on the results of previous studies it was found that the achievement of learning outcomes of students geometry material is still low, even the mathematical and scientific ability of students in Indonesia is still low at 49% and 39%, this score is far inferior when compared to other Asian countries [16]. Likewise, with the results of Ainiayah's research which concluded that the spatial ability of students is classified as very weak in the material of building space, in other words, students still have difficulty understanding concepts and principles on geometry material [17]. Among the failure of students' understanding of geometry material is caused by teachers being less creative in using learning media and more likely to explain the lesson with lecture and textbook methods [18].

In principle, learning geometry means learning visual patterns that can educate students to improve their thinking skills by using visual media. Then the use of technology such as software will be able to influence students to understand geometry material easily and fun, including abstract reasoning skills needed for higher levels of mathematical thinking [19]. So, according to the authors the use of technology is very important as a learning media innovation. Based on these problems, researchers designed an application called VirGo (virtual geometry) as a digital teaching aid based on augmented reality in mathematics learning.

Augmented reality is a technology that combines two or three-dimensional virtual objects into a real three-dimensional environment, then the tool projects these virtual objects into real objects [20]. Augmented reality-based applications have three principles: the system can display 3D objects (three dimensions) intact and realistic, can display animated processes described in the material on teaching materials, and can respond to several user actions (interactive)[21,22].

The design of this application aims to create a new atmosphere that is more interactive and real by displaying geometrical objects visually in the form of 3D (three dimensions) in mathematics learning. Students not only learn but also play so that mathematics no longer seems boring to students in school. In addition, this application is expected to be able to support teaching materials and can provide more knowledge for each user.

2. Research Method

To design the application in this study, the authors used the prototype model method, which was referred to several prototype model research experts who had often been referred by several previous researchers. In the prototype model there are three stages that must be carried out [23,24]. That stage can be seen in the following figure 1:

Figure 1. The Stages of the prototype model research method

The prototype method begins by analyzing the needs of consumers, then the writer begins to make digital props desired by the customer. In the next stage customers who will use the product meet to plan their goals and needs and collect data. Data sources used are primary data sources and secondary data sources. Primary data sources obtained through observation to directly review conventional teaching aids commonly used in geometry material at the school. The data obtained in the form of the results of the documentation needed in making design and 3D objects (three dimensions) as a marker (marker). Furthermore, secondary data sources are obtained through the collection of literature reviews that aim as basic information in designing markers.

At the build/revise mock-up stage, the design process is carried out quickly and the design represents all known aspects of the software and forms the basis of making a prototype. Based on customer needs regarding the objectives to be made at the listening to customer stage, the next step is to build or build digital props quickly. The design begins with the process of modelling the object of building using the 3D modelling application. Furthermore, designing and building AR applications using 3D game engine applications. While the Vuforia SDK is used as a plug in to simplify the process of tracking AR and C # markers as a programming language.

Next, the final stage is the customer test-drives mock-up (evaluation). This stage is done to evaluate the prototype that has been built and is used to clarify software requirements. The evaluation carried out aims to determine whether digital props are in accordance with the customer's initial needs or not. After the digital teaching aids are tested, various deficiencies will be seen in the digital teaching aids, whether the visual aids are in accordance with the customer's initial requirements or not. If it is not appropriate, the developer will repeat steps one and so on.

3. Result and discussion

As the author has explained in the background section of this article that VirGo (virtual geometry) is designed as a digital display tool that displays material to build flat side space in three-dimensional shapes. With the presence of digital teaching aids, it is expected to make a pleasant learning atmosphere for students so that learning is not rigid and monotonous. The VirGo three-dimensional display (virtual geometry) will be displayed on a marker as can be seen in Table 1.

Table 1. Display of virtual geometry markers

Marker	Information	Marker	Information
	Cuboid Marker		Cube Marker
	Pyramid Marker		Prism Marker

Furthermore, related to how the mechanism of the steps of digital teaching aids based on augmented reality can be seen in Figure 2 below. The process will begin by opening up digital props in which various types of markers have been available in the form of space drawings. Then the marker is placed in front of the camera, then the camera will scan and digital props will detect the marker. Furthermore, three-dimensional objects will appear according to the marker. The working mechanism of the VirGo is presented in figure 2.

Figure 2. The working mechanism of the VirGo

After going through the design stages and obtaining system requirements data, digital props are produced with an interface implementation, which is the display of digital props. Interfaces require scenes to handle each process and simplify system work. Each scene has a relationship with one another. Following is the interface of digital teaching aids [25,26].

3.1. Splash Screen Page

The splash screen page contains the VirGo logo (virtual geometry) as a transition or moves to the main menu. The splash screen page is presented in figure 3.

Figure 3. Splash screen page

3.2. Main Menu Page

The main menu is the initial display that has controls in the form of buttons or icons that allow users to interact with data with the button. The buttons or icons contained in the main menu consist of learn, video, credit, settings, and exits. The learn button is used to start the Augmented reality screen so students can go to the next page that provides a learning page. The video button contains a learning tutorial that discusses material and examples of geometry questions in more depth, as well as Olympic questions related to geometry material. While the credit button contains information about the application. Then the settings icon is used to provide instructions regarding application settings. The exit icon is symbolized by the cross-function to exit the application. The main menu picture is presented in figure 4.

Figure 4. Main Menu

3.3. Learn Menu

This section is the page after the main menu. The learning menu page is the main menu of this digital teaching aid, where there are buttons or icons that can be used as a scanning marker process that will display three-dimensional objects. The buttons or icons are, among other things, the wake button in the form of cube, cuboid, pyramid, prism, cylinder, cone; video icon, camera, games icon, help icon. The space build button contains the results of a scanning marker that displays three-dimensional objects from the space building. If the user presses one of these buttons, then a command will appear to enter material such as length, more, and height according to user needs. Furthermore, it will automatically produce three-dimensional object output according to the size input by the user along with information about the volume and surface area of the building. The video icon is used as a shortcut key to switch to the video menu. The camera icon is used to switch from the back of the camera to the front of the camera. The games icon is used as a shortcut key to switch to the games menu that has been provided. While the help icon is used as a shortcut key to switch to the help menu which contains application guides. The learn menu page is presented in figure 5.

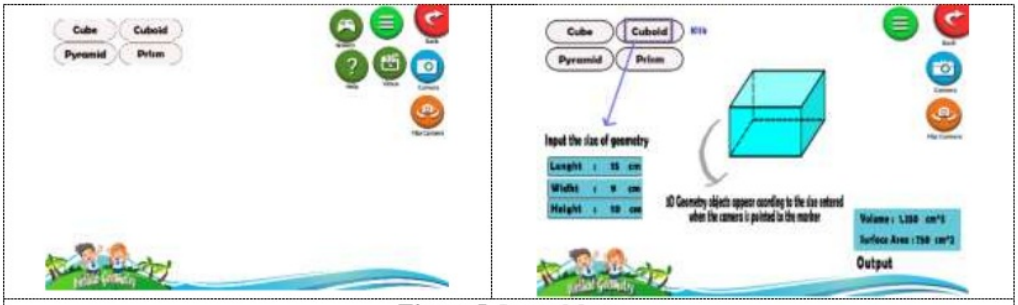

Figure 5. Learn Menu

3.4. Video and Help Menu

In this section, there is also the main menu of learning videos about geometry materials. On video menu, there is a tutorial discussion in the form of sample questions and national science olympic questions. This learning video is equipped with three-dimensional animation. Video and help menu is presented in figure 6 &7.

Figure 6. Video Menu

Figure 7. *Help* Menu

3.5. Credit and Exit Menus

This section contains an explanation of digital props and information about the developer. The exit menu is used as a button that displays a command to exit an application that has finished being used. Figure 8&9 show the credut menu and exit menu.

Figure 8. Credit Menu

Figure 9. Exit Menu

The last step in this research is testing, namely testing of digital props and markers. Testing on digital teaching aids as a medium of learning mathematics using black-box testing techniques. This test will test the effectiveness and success of the features contained in this digital teaching aid. In the following table 2, we will describe the results of testing the effectiveness and success of the applications that have been made during the study. The effectiveness results of the virtual geometri application are presented in table 2.

Table 2. Testing the effectiveness of virtual geometry applications

Testing	**Scenario**	**Expected results**	**Testing Result**	**Conclusion**
Splash screen page	Open the application	Goes well and can be open	According to expectations	Valid
Main menu	Choose *learn,* video, and *Credit* menu	Move to the next page according to the selected menu	According to expectations	Valid
Learn menu	Choose every button in geometry and hyperlink	Enter the selected content	According to expectations	Valid

Testing	Scenario	Expected results	Testing Result	Conclusion
Video menu	Press the buttons on the video menu	Enter the selected video content	According to expectations	Valid
Help menu	Press *help* menu button	Appears guide is displayed	According to expectations	Valid
Credit menu	Press the *credit* menu button	App developer's info is displayed	According to expectations	Valid
Exit menu	Press *exit* menu button	Exit from application	According to expectations	Valid
Back button	Press *back* button	Back to previous page	According to expectations	Valid
AR screen	Object compatibility with markers	See the suitability of 3D objects with markers	According to expectations	Valid

Based on the results of tests that have been carried out on students in three junior high schools in Padang, the results of the analysis show that digital teaching aids are in line with expectations with a high level of validity and according to the desired expectations and goals. In other words, the design of digital teaching aids applications can be used well and is very effective as a learning medium. To strengthen the results of the study the authors also conducted an analysis of the camera detection process of each marker with a certain distance. Table 3 below is a description of the results of the test analysis conducted by a team of experts who the authors requested as an analyst and assessor. Table 3 below is presenting the testing camera results.

Table 3. Testing the camera detection process of the Marker

Marker	Distance (cm)							
	30	40	50	60	70	80	90	100
Cube	√	√	√	√	√	√	√	√
Cuboid	√	√	√	√	√	√	√	√
Cylinder	√	√	√	√	√	√	√	√
Cone	√	√	√	√	√	√	√	√
Sphere	√	√	√	√	√	√	√	√
Prism	√	√	√	√	√	√	√	√
Pyramid	√	√	√	√	√	√	√	√

(√) = Objek 3D shown (–) = Objek 3D not shown

To be more interesting, the results of this study will be discussed with various theories and the results of previous research researchers who discussed this problem in the same context and issue. Previously, the writer had touched that mathematics was one of the subjects that students disliked at school. Actually this problem is very much realized by the teacher, it's just that the majority of teachers do not yet have pedagogical and professional competencies to overcome the problem of learning difficulties of students [27,28]. Whereas with the development of digital technology today, it provides choices and opportunities for teachers to be creative in conveying subject matter especially the material of geometry in mathematics learning [29]. In the context of mathematics learning students can actually learn through three basic aspects, namely enactive, iconic, and symbolic. Enactive stage is the learning stage by manipulating concrete objects or objects, then the econic stage of the learning stage using pictures, wh the symbolic stage is the mathematical learning stage through the manipulation of symbols or symbols[30]. Learning mathematics is a process of constructing or constructing concepts and principles, not just teaching that seems passiv nd static, but learning must be active and dynamic [31]. The results of previous studies have proven that, the use of digital technology designed in the form of adroid applications as the authors have implemented in this study is very influential on student learning outcomes, especially in geometry material [32,33,34].

Basically augmented reality is a geometry learning media that is able to display instructional material visually in the form of three dimensions. Referring to the design results and application effectiveness that the authors have done and tested in this study, it has been proven that virtual geometry applications based on augmented reality have been able to create a new atmosphere that is more interactive, fun for students in learning mathematics. In addition, with the application it turns out that it has also been able to change students' perceptions of mathematics that previously seemed more difficult, rigid so that it quickly made the learning atmosphere bored and tedious. The results of this study were supported by previous researchers who concluded that, learning mathematics that still uses traditional techniques, media and ways of learning are no longer relevant to current educational development [35]. On the contrary, teachers are required to be creative and try to always improve their pedagogical and professional competencies so that they are able to answer the challenges of an increasingly complex and challenging world of education [36,37].

In the end, according to the author, any form of learning is always dynamic and holistic, the success of a learning process is not determined by the good education system, the neatness of the curriculum, the complete learning facilities, or the high welfare. Because the success of a learning process is influenced by various complex factors such as teacher competency and creativity. On the student side there are also aspects of will, interest and talent, but to foster the desired aspects of these learners the teacher needs to use a variety of ways, as for ways that the teacher can do is like the use of an adroid application designed in the form of augmented reality in learning geometry as the authors have implemented in this study. Because basically the learning atmosphere of students in the classroom is very determined by how a teacher designs the learning itself [38]. If the teacher tries well in designing learning it is very influential on learning outcomes, but if learning is rigidly designed, not interesting it will also have an impact on learning outcomes themselves [40, 41, 42, 43, 44, 45].

4. Conclusion

This research has succeeded in designing and testing how effective virtual geometry applications are in mathematics learning based on augmented reality. Referring to the test and analysis results as the author explained in the results section and discussion of this article, as a whole it can be concluded that mathematics learning can be of interest to students if the material provided is taught through various learning tools and media. There are various interactive mathematical media that have been designed by experts to increase the interest and understanding of students at learning time including using augmented reality with a virtual geometry approach.

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