Design Gamification Applications in Mathematics Learning Using Augmented Reality

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Abstract. Students grow up with digital technologies so that they have new attitudes and learning styles for learning. Gamification enhances the involvement of students with the material and problems encountered. In this papper, we reflect on the design of gamification experience in mathematics learning using augmented reality for helping students understand and solve real world problems. We focus on designing applications for game-based learning and solving real-world problems for learning environments. This study uses Research and Development (R&D) with the ADDIE model (analyze, design, develop, implement, and evaluate). This study focuses in analyze, design, and develop step. The result of this study is the first feature of the application is facilitating the students to measure the real-world object using digital measuring tools, the second feature of the application is facilitating the student to explore real world problems that accompanied by a virtual pet through augmented reality then get credits points for solving the problems and use the point to upgrage the virtual pet . The limitation of this study is the application needed a special operating system to operate properly, the device needed AR Core embedded device. Our finding that designing gamefy application needed careful consideration of game features to enhance the students' involvement and intentive in mathematics learning with excitement.

Key words: Gamification, Mathematics Learning, Augmented Reality

INTRODUCTION

The technology used in learning needs to have several things including (1) presenting a proof process, (2) presenting and connecting several representations, (3) supporting case-based reasoning, and (4) providing convenience for students (Cullen et al., 2020). This is in line with the statement that the education system is being directed towards achieving broader goals and utilizing technology to prepare students to cope with new emerging challenges (Antónia et al., 2018). Augmented reality technology became popular after various games adopted augmented reality, augmented reality is also gaining popularity as a medium that can be used in the learning and teaching process. Augmented reality is a combination of real and virtual objects in a real environment, running interactively in real-time, and there is integration between objects in three dimensions, namely virtual objects integrated into the real world or can be referred to as "improvement of the real world by adding simulation elements (Azuma, 1997; Medina Herrera et al., 2019). AR can be displayed in the form of various objects developed by developers and can be manipulated by users. AR can be a good lesson if it is developed properly (Sommerauer & Müller, 2014). Introducing concepts with several different representations which include using manipulatives, showing pictures, drawing problems, and offering symbolic representations to address different learning styles will help students to understand concepts in a better way (Mutawah et al., 2019). The concept of AR refers to real-time information that is enhanced and created with the help of smart devices and applications such as smartphones, tablets, wearable headsets, and immersive technologies (Wu et al., 2013).

The AR is heading to enrich the perception and knowledge of the real environment by adding digital information related to the real environment. In addition, AR complements the real-world environment with virtual, computer-generated digital information, allowing users to experience the interaction between two computers (Azuma, 1997; Azuma et al., 2001). Mostly the information in visual, sometimes in auditory. In most AR applications, users visualize synthetic images through glasses, headsets, video projectors, or even via mobile phones/tablets. Furthermore, virtual objects or object visualizations can display information that users cannot directly see on paper or see with the human senses. Augmented reality has been officially defined in 1997 by Azuma (1997) and consists of the three characteristics are as

follows Combining real and virtual, Interactive in real time, and Registered in three dimensions. The meaning of "combining real and virtual" is that for the user it will appear that what he sees as virtual objects will coexist or as part of his real environment (Azuma, 1997). The combination of real and virtual objects is in the same space and time, so it is interactive in real time. Objects are combined in three dimensions, making virtual objects seem real because our physical environment is three-dimensional (Azuma, 1997).

Technological developments have made it easier to access games, gamification, and simulations. Some of the things that make games, gamification, and simulations common and easily accessible are as follows (1) games are easier to make using widely available game engines, (2) Many university graduates develop games and venture into various fields that are not only focuses on games such as business and education, and (3) Games are increasingly accessible via smartphone devices that can be taken anywhere, so they can access games anywhere (K. Kapp et al., 2014). The popularity of gamification in education has become a concern for designing gamification in learning environments (Kamalodeen et al., 2021; Nand et al., 2019).

Game mechanics have also become commonly known by students at this time. The game mechanism directs the user to increase the user's higher commitment and motivation when engaging in game activities and processes. The approach to using games improves interaction and motivates users and plays an active role in continuing to play games, this conclusion is a conclusion for companies but in the field of education also has the same situation. (Ružic & Dumancic, 2015).

Gamification is the use of game-based mechanics, aesthetics and presenting game thinking with the aim of involving users in the process of mastering skills, motivating action, promoting learning, and solving problems (K. M. Kapp, 2012). Gamification or game-based techniques when used properly can enhance student information, learning and engagement
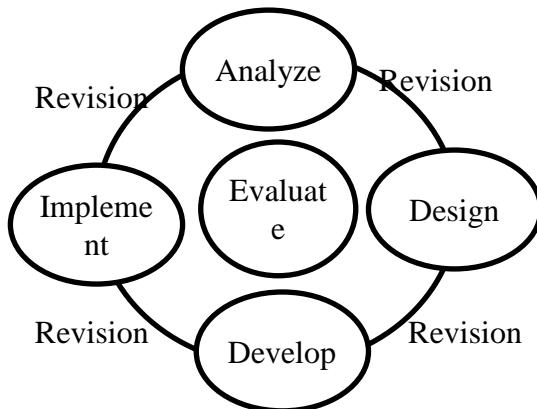
(K. M. Kapp, 2012). Gamification is bound but not identical to game based learning, gamification focuses on using game design elements but in a non-game context while game based learning focuses on acquiring skills and knowledge through games (Welbers et al., 2019). Gamification in education aims to improve the quality of learning outcomes by applying game dynamics and mechanics and incorporating various game elements into the field of education. Giving awards, the process achieved, points, challenges, storylines, and quests are game elements that can be included in the learning process.

The use of game elements in learning that does not change the learning content for example giving points after completing challenges. The use of game elements in learning that transforms learning content into a game, for example packaging math problems in the real world as a quest. Gamify learning incorporates game elements to enact a game-like experience to achieve predetermined goals and have a positive impact on student motivation (Dichev et al., 2020).

The problems experienced by learning in general are not fun, students are not challenged, and students do not feel involved in learning. Gamification in the field of education offers facilities for students to carry out a fun and challenging learning process and be more involved in the learning process. Gamification in this study is intended to teach skills in learning mathematics to solve problems in the real world according to the scenarios that have been prepared. The purpose of this research is to design an application for learning mathematics using augmented reality with gamification. This study presents a selection of gamification-based applications using augmented reality that used in learning mathematics and presenting learning experiences in gamification.
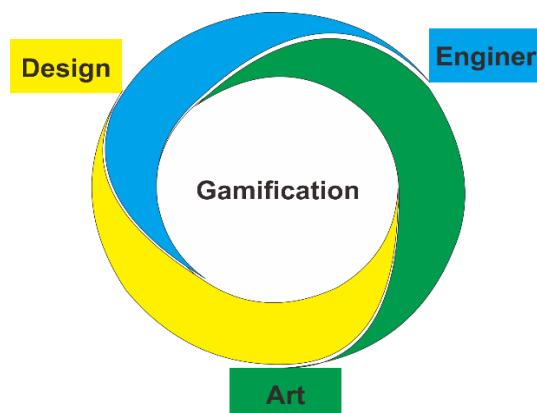
METHODS

The study use Research and Development (R&D) method and ADDIE (Analyze, Design, Develop, Implement, Evaluate) model (Branch, 2009). The ADDIE steps are as follows:

Figure 1. The ADDIE Steps

This research focused on analyze, design, and develop step. Analyze step is analyzing and identify the performance gap and user need. The analyze step included validate the performance gap, intructional or learning goal, confirm the students or audience, and identify resources. The design step is designing desire performance for the application. The design step include design application feature, application mechanics, and designing application user interace. The develop step is to develop generate learning resources. Develop steps included develop content, develop application mechanics, and develop all user interfaces from the application opening by the user until the application closing by the user.

RESULTS AND DISCUSSION

Gamification combines design (instructional design and game design), Engineer (tools and game system), and Art (interface, environment, and character), it show bellow.

Figure 2. Gamification Procces

Instructional design and game design in this research are closely related activities. The gamification application created is intended to make students interested in solving the problems presented in gamification. Games are designed to give students the opportunity to explore the real world accompanied by virtual pets. The first student is provided with a basic virtual pet (given free of charge) then students can upgrade their virtual pet after getting enough points by solving the problems given. The problems given to students are adjusted to the students' abilities. The teacher designs the problem based on the GPS point so that the teacher can start from one GPS point to another GPS point. Each GPS point is given a problem and can be designed in such a way that it fits the student's abilities and achieves the teacher's expectations. Students carry out exploration to find problems given by the teacher with guidance/direction in the form of augmented reality and accompanied by virtual animals to the point where the problem is located. When students solve problems, students need to access virtual measuring tools to help solve problems.

The tools used in applications made using Unity and AR Core. The collaboration of Unity and AR Core allows presenting augmented reality applications without the need for markers so that they are freely accessible anywhere. The use of applications with AR Core needs to be calibrated with the smartphone's GPS location point so that it can provide accurate location points and directions. The application also requires internet access so that the location is presented in real time and increases the accuracy of the directions given in the form of augmented reality. The game system is made as easy as possible so that it is easily understood by students, students open the application and are immediately directed to the location points that have been made by the teacher and are immediately given directions in the form of augmented reality to reach the specified location point. Virtual animals are made to continue to follow users whether they are connected to the internet network or not connected to the internet so that they become loyal pets. After completing the problems given, students will earn points that can be collected and used to upgrade pets so that students are excited to earn points.

The User Interface (UI) of the application is made simple but still has an aesthetic value that makes students feel comfortable seeing the appearance of the application. The application has a look and color that is not overwhelming or simple and elegant. The virtual environment created in the application is intended to match the pet that has been created and give the impression of an environment that is suitable for

the animal. The pets that are designed are also made with themes so that they have various types of upgrades, ranging from simple animals to virtual animals that have been upgraded to the maximum. Virtual pets accompany users to various locations that have been arranged so that students solve problems that have been designed by the teacher. Pets are always loyal to follow users and are around users in exploring the real world to achieve problems that have been prepared by the teacher.
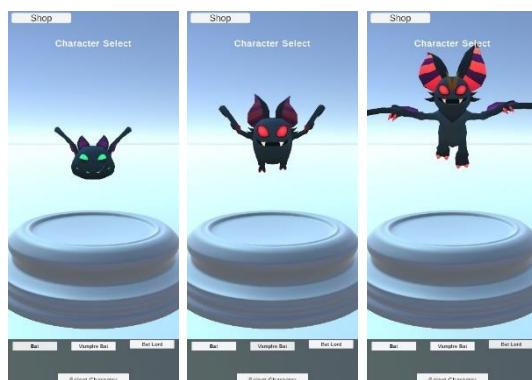

Figure 4. Virtual Pet Selection Menu

The given problem will appear when the student walks closer to the specified location. This location can also be designed from one location to another through Google Earth so that the problem solving process from one point to another is for example as follows.

Figure 5. The Example Of Making Problem Location Points

The pet is always in front of the user and when the user follows the directions provided by the application. The directions provided by the application have two types including the direction of the road that is below and there is also a written direction that advises the user to take or choose a path that can be used to reach the point where the problem is being addressed. In the written direction there is a direction that needs to be taken and the distance that needs to be traveled until a new direction appears that

will direct the user again. Users who have approached the location point with an estimate of 10-15 meters will appear questions that present pictures and problems that need to be solved so that users will find it easier to find the intended problem, after arriving at the location there will be additional information that the user is already at the location.
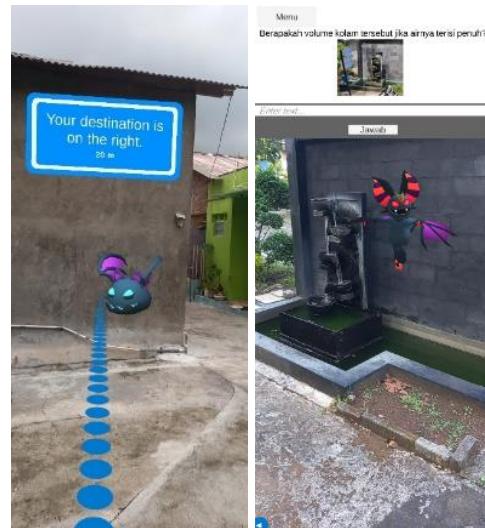

Figure 5. Explore View (Real World Exploration)

When reaching the location the user can solve the problem presented with a virtual measuring instrument that can be manipulated and has a real size so that the use of a virtual measuring instrument can make it easier for users to solve problems. The size information of objects measured in the real world is next to the sizing tool (white line). After completing the questions encountered and answering them correctly, the user will get credit points that serve to buy and upgrade the pets they have.

Figure 6. Measure View (Virtual Measuring Tool)

Virtual measuring instruments can measure various objects in various directions but are still limited to straight lines. The Et AR World app requires an AR Core supported device and not all devices have it.

The augmented reality feature provided by this application allows students to learn with a new learning environment, learning in a real environment with various additional features through virtual objects. The application is designed to present a gamified learning environment to make students face math questions or problems using student ingenuity, arouse students' creativity and imagination, this allows students to gain new knowledge or strengthen what students already have (Molina-Villarroel et al., 2021).

Gamification of the process in learning can be carried out effectively through the following stages (Stoyanova et al., 2017).

Understanding the target audience and context

Junior high school students aged around 12-15 years who still need assistance with the abstraction process so that the use of virtual objects can help students abstract the knowledge that is being built, students can also work individually or in groups so that activities are made collaboratively. This is in accordance with the extensive technology education efforts in schools to support teaching/teaching, and student learning leads to learning points, namely by involving and empowering students. (Chu et al., 2017b).

Defining learning objectives

The learning objectives to be achieved in learning activities using gamification applications using augmented reality are to make students think deeply and understand mathematical material, especially data and space geometry material with the motivation that is built in students through solving real problems in the real world. This is in accordance with the extensive technology education efforts in schools to support teaching/teaching, and student learning leads to assessment points that is by measuring what is important to measure (Chu et al., 2017b).

Composing experiences

The student experience in learning is very different from usual learning because the features provided by the application provide access to learning in a real environment and give an authentic and real impression so that it gives a deep impression and students can still achieve the learning outcomes expected by the teacher). This is in accordance with the extensive technology education efforts in schools to support teaching/teaching, and student learning leads to teaching points, namely by preparing learning and connecting the learning carried out with the experiences gained by students through the activities carried out. (Chu et al., 2017b).

Identifying resources

The resources needed to run this application are now quite affordable because it only requires a smartphone supported by AR Core and internet access, this can be achieved without spending a lot of money, but it is necessary to choose the appropriate smartphone because not all smartphones are supported by AR Core. Students' abilities also need to be considered so that they can provide appropriate content and pedagogics for students. This is in accordance with the awareness about the integration of technology with learning and pedagogical content ultimately leads to regular use of technology, through appropriate training and support, leading to more creative use of technology for teaching and learning (Chu et al., 2017a).

Applying gamification elements

The gamification mechanism used in the application using augmented reality is a system of credit points that can be obtained by solving problems and these points can be used to upgrade the virtual pet owned. This needs to be considered so that the gamification application is in accordance with the expectations of making the application. Some things that are not right in the selection of gamification include only (1) because it is cool, amazing, or fun, (2) many people do it, and (3) learning will be easy / effortless learning (K. Kapp et al., 2014). Gamification was chosen to implement an interactive learning experience such as (1) creating interactive learning delivery, (2) providing opportunities for deep thinking and reflection, (3) authentic/hands-on practice (K. Kapp et al., 2014).

Virtual animals and virtual measuring instruments use augmented reality technology which allows virtual animals and virtual measuring instruments to blend into the real world so that users experience additional features that are difficult to obtain when using real objects. AR technology enables the development of games that occur in the real world coupled with virtual information and can provide educators with new ways to deliver learning materials and provide highly interactive learning (Dobrovská & Vaněček, 2021). This application provides virtual animals that are always around the user so this is a feature that makes users feel not alone in solving problems

prepared by the teacher. The pet system is an important thing in the game design process and is a trend in game development, psychologically, every player wants to have a beautiful and loyal pet partner (Shui et al., 2009).

CONCLUSION

The result of this study is the first feature of the application is facilitating the students to measure real world using digital measuring tools, the second feature of the application is facilitating the student to explore real world problems that accompanied by virtual pet through augmented reality then get credits points for solving the problems and use the point to upgrage the virtual pet, this is providing encouragement to students such as challenges, goals, and making progress are all traits that engage and encourage humans. The limitation of this study is the application needed special operating system to operate properly, the device needed AR Core embedded in the device, so to implemented this application properly the students and teacher need to prepare all the application needs.

Important things that need to be considered in designing gamification include (1) what are the main reasons for using gamification, (2) why not use other alternatives, (3) whether the design is in accordance with the needs and desires of users, (4) whether the design has presented activities that are suitable for the user. Our finding that designing gamefy application needed careful consideration of game features to enhance the students involvement and intentive in mathematics learning with exitement.

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