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EDUCATIONAL GAME FOR LEARNING COMPUTATIONAL THINKING IN A LOW BUDGET VIRTUAL REALITY ENVIRONMENT

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Abstract

Virtual reality (VR) is a technology that can create a simulation of real objects in a virtual environment more interactively. In terms of budget, VR devices can be categorized into low budget and high end. However, both of them can still carry out the same interactive simulations, such as educational games. This research aims to develop an educational game based in low-budget VR environment for learning computational thinking (CT), one of the 21st century skills that students need to learn. The method used is Design and Development Research (DDR) that consists of five stages: analysis, design, development, testing, and evaluation. Participants involved in this study are 30 students of vocational school (SMK) majoring Computer and Network Engineering. Evaluation conducted through Technology Acceptance Model (TAM) framework that consists of perceived usefulness (PU), perceived ease of use (PEU), attitude toward using (ATU), and intention to use (ITU). Based on the data obtained and the analysis performed, the Cronbach's alpha score of PU and PEU were 0.714 and 0.614, respectively. Meanwhile, the Cronbach's alpha score of ATU and ITU were 0.754 and 0.882, respectively. PU and PEU are positively correlated with ATU, while ATU is also positively correlated with ITU. It means that the ease of use of the application and the usability aspects of the developed application have a positive effect on user attitudes. This positive behavior is also positively correlated with the intention to use it again on another occasion. Thus it can be concluded that this educational game based in low-budget VR environment can be used for learning CT. It can be seen from the analysis and some positive comments from students, like participants wish they can use this learning approach in the other subject.

Keywords : virtual reality, educational game, low budget, computational thinking, technology acceptance model

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INTRODUCTION

Virtual Reality (VR) is a computer technology that can create objects and artificial environment to be simulated and presented in a virtual or digital environment. VR can create interactive simulations that allow users to make more "immerse" in the created world so that feeling if they are in that artificial environment [1]. For example, research conducted by Arayaphan et al., (2022) [2], creating a virtual museum based on the real condition of artifacts and its environment from the museum so that users can feel the existence of museum and can see the original form of the available artifacts. Another example, a study conducted by Seifan et al. (2020) [3], developed a virtual bioprocess engineering laboratory to help students learn about the principles of fermentation and laboratory safety rules. From the study, it was found that students felt safer and could conduct experiments better.

Viewed from the advantages, VR technology can be regarded as one of the modern tools that can be used to promote development and innovation in various fields [4], starting from education [5], tourism [6], [7], until entertainment industry [8]. VR is even said to be one of the 21st century learning aids [9]. Meanwhile, when viewed from its aims, many studies have used VR technology for various purposes, for example to improve learning and training [10], to improve longer memory [11], to improve pedestrian skills for children with autism spectrum disorders [12], and even for learning computational thinking (CT) [[13], [14].

Discuss about budget of VR devices to develop an application, VR technology can be grouped into two categories, namely low-budget and high-end VR [11]. Low budget VR is a VR device that has a low cost, for example Samsung Gear VR, and Google Cardboard. Meanwhile, high-end VR is a VR application that is developed using more expensive devices, such as the HTC Vive and Meta Quest 2. If the price of a high-end VR device can be obtained at a price of around five million rupiahs, the low-budget VR devices can be obtained even only for less than a hundred thousand rupiahs, for example VR Box. In terms of features, of course low-budget VR has limited capabilities compared to high-end VR devices which have advantages in haptic sensors and controllers. However, even though it is inferior in terms of features, low-budget VR does not mean that it cannot be used to create a simulation that make users feel immersed or enter to the VR world.

Therefore, this research tries to explore low-cost 21st century learning tools, namely low budget VR devices, for learning one of the 21st century skills as well, namely CT [15]–[17]. CT is a thought process involved in formulating problems and their solutions that are represented in a more effective way to solve [18]. The CT definition actually varies since there is no consensus that determines the exact operational definition of CT [19], [20], but researchers stated that such a definition is not too important nor too disturbing [21]. That is why many parameters, components or elements are included in CT, but the core of CT that researchers often recommend consists of four skills [22], [23], namely: (1) decomposition, the ability to break down large problems to be a smaller part that more easy to tackle; (2) pattern recognition, the ability to find similarities or patterns among the problems that have been decomposed; (3) abstraction, the ability to filter out what information or problems that should be resolved first or ignore it based on the recognized pattern; (4) algorithm design, the ability to design or develop steps to solve problems.

Among prevalent topics, such as computing, programming, coding, and problem-solving, CT become a core and has an important role in while solving problems [20]. So it is very important, especially for someone who wants to learn programming, learning CT as the foundation of the solution behind all digital technology solutions, software, and systems todays.

However, most of CT learning is conducted using visual block programming software like Scratch, App Invertor, Construct 2, Kodu, and Blockly [20]. Meanwhile, learning CT using VR technology are lacking. Even, using low-budget VR device.

Based on the aforementioned, this study aims to develop an application based on a low-budget VR for learning CT. The developed apps, is a game that makes users more active in learning while playing. Players can still feel as if they are in a room or environment where they are playing or immerse even though the device used is low-budget.

METHOD

A. Research Design

Method used in this study is Design and Development Research (DDR), a systematic study starting from the process of design, development, and evaluation with the aim of building a basis or empirical evidence for the creation of an instructional and non-instructional product and tool, either for a new or enhanced model. and regulate its development [24]. DDR

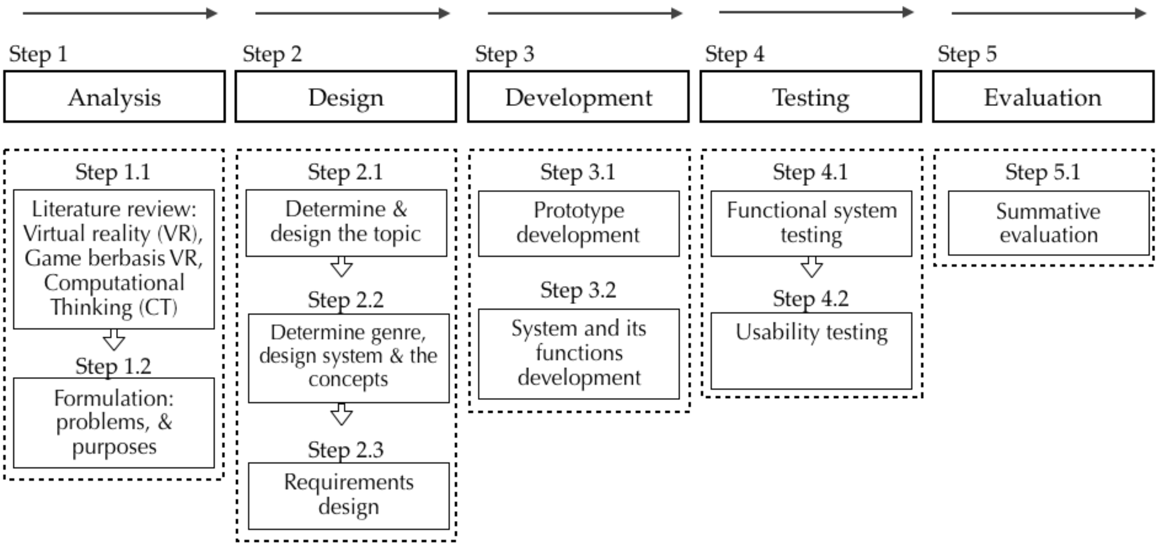

Figure 1. Research design steps

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covers a wide spectrum of activities and interests, that can be: (1) studies about processes and the impacts of a particular design and development effort, or (2) studies about the whole design and development process or certain parts of it. The first type deals with the study about design and development of product, while the second type focuses on the design and development model and process itself. This study is more precise with the second type.

This method was chosen because the development of a new application product was needed to implement the proposed strategy and then evaluate it. The application product is educational game that installed in a low-budget VR device. All processes and stages of this DDR approach are documented in a model, namely: analysis, design, development, testing and implementation. The detail stages carried out in this study are presented in Figure 1.

The analysis step consists of two sub-phases, namely literature review and formulation. The literature review related to previous research discussing VR, VR-based games, and CT obtained from Google Scholar or others indexed in reputable international databases. From the analysis, the problem was formulated to determine objectives so that has a strong argumentation base to conduct this research.

The design or design stage consists of three sub-phases, namely: (1) designing topics that will be raised in learning and implemented in games, (2) selecting game genres and designing game systems to be developed, and (3) designing and defining requirements required for game development. The three sub-phases are very important because they will determine the shape and form of game applications that are influential in the application development stage.

The development step is the stage of developing a prototype of VR-based game application and construct its functionality. Both prototype development and its function are complement and correct each other. Functionality development based on the prototype, while developing prototype based on its functionality, since the application development is not always perfectly same as the design that has been made. This way to reduce obstacles while development so that applications can be completed. Even though sometimes the prototype was little bit different from the design, but it is not affect to the goals and purposes.

The testing step is examining the application from various aspects, start from the user interface, the suitability of images and colors used, until the functionality. If all the functionality features are running well and accordance to expectations and planning, it can be said finished. Functional testing involved participants to obtain response and useful feedback for further development.

The evaluation step is the last phase in this study. It was a summative evaluation, where all the processes were evaluated from the beginning until the end of research. All the processes and stages of the development were evaluated to describe the conclusion based on the data and facts occurred while conducted testing.

B. Game System Design

Game system design was mapped out using use case diagrams (UCD) to make easier for viewing the interaction between game systems and the player. In general, the UCD game application designed in this study can be seen in Figure 2. When the game application is running, the player will see the main menu that contains several options, they are: info, choose level, and exit menu. The info menu contains information about the game, how to play and developer info. While the exit menu is the option when the player wants to escape from the game application. Before playing, the player has to choose the available level to play. While playing the game, the player will have two possibilities, they are: (1) completed, means that it is accordance to the rules, missions, and the goals of the game, or (2) game over, means finished but not appropriate to the rules and regulations applied in the game.

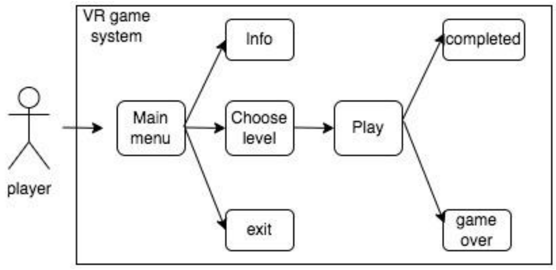

Figure 2. Game system design

More specific, the gameplay is designed in a flowchart as shown in Figure 3. After the player selects the level, the game system will provide tasks or missions that must be accomplished. The mission in this game is to design a path that is illustrated in the form of a bridge in the game. The path or bridge will be a reference for players so they can walk through the end point. Players have to provide input or commands to the system so that automatically construct paths. The paths generated by the system based on the player input, such as up arrow, right, left, and one looping input. These commands are adapted to the basic concept of programming where program execution output is created based on the existing command input and logic. Hence, the players can learn CT concepts using the basic concepts found in programming. If the input is entered according to the game rules then the mission is completed successful, but if it is not appropriate it can be said to be failed, so the player must start again to compile and input the commands until appropriate to the game system requested.

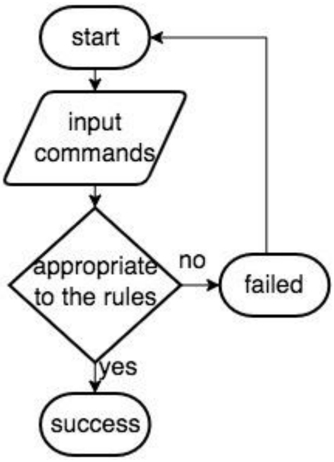

Figure 3. Gameplay flowchart

Table 1. Questionnaire adopted from TAM

Code	Question
	Perceived usefulness (PU)
PU1	This virtual reality-based educational game helps me in learning computational thinking
PU2	This virtual reality-based educational game is suitable for learning in the classroom
PU3	Each level in this virtual reality-based educational game helps me in to learn algorithms
	Perceived Ease of Use (PEU)
PEU1	This virtual reality-based educational game is easy to use for learning computational thinking
PEU2	The user interface of this virtual reality-based educational game is easy to understand
PEU3	Overall, this virtual reality-based educational game is easy to learn and use even without a manual
	Attitude Toward Using (ATU)
ATU1	Using virtual reality-based educational games for learning computational thinking is very fun
ATU2	Learning computational thinking using educational games based in virtual reality is very interesting
ATU3	This virtual reality-based educational game is very suitable for learning computational thinking
	Intention to use (ITU)
ITU1	I am very interested in using virtual reality again for learning other topics
ITU2	At another time, I'm interested in using this virtual reality-based educational game again
ITU3	I really like the learning model using virtual reality media in the classroom

C. Conceptual Framework & Instruments

To make it easier in organizing ideas and clarify the concepts [25], a conceptual framework was designed, that contains an explanation of the variables involved in this study. The aim is to evaluate VR-based game applications that have been developed. Figure 4 is the conceptual framework adopted from the Technology Acceptance Model (TAM) proposed by Davis [26]. Several studies have also adopted this model to evaluate the research that has been conducted, including in multimedia learning [27], online learning environments [28], and educational games [29].

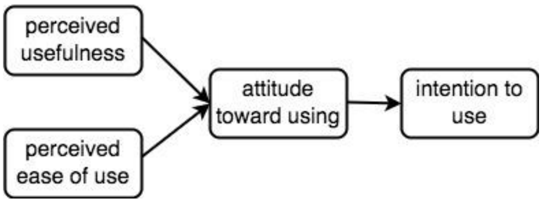

Figure 4. Conceptual framework

The conceptual framework consists of four variables, namely: (1) perceived usefulness (PU), (2) perceived ease of use (PEU), (3) attitude toward using (ATU), and (4) intention to use. The development of instruments for data collection is based on the TAM variable adopted from existing research [27], [30]. The questionnaire instrument can be seen in table 1. The answers consist of 5 Likert scale options which state: 1 strongly disagree, 2 disagree, 3 are undecided, 4 agree, and 5 strongly agree.

Tabel 2. Participants demographic

	Option	n	%
Age (years)	14	3	10%
	15	22	73,3%
	16	5	16,7%
	Total	**30**	**100%**
Ever learn CT?	Ever	15	50%
	No	15	50%
	Total	**30**	**100%**
Ever learn programming?	Ever	18	60%
	No	12	40%
	Total	**30**	**100%**
Time of playing a game in a day (hours)	<1 hour	12	40%
	1 – 2	5	16,7%
	2 – 3	3	10%
	3 – 4	4	13,3%
	>4hours	6	20%
	Total	**30**	**100%**
Ever using VR device?	Ever	19	63,2%
	No	11	36,7%
	Total	**30**	**100%**

D. Participants

Participants involved in this study were 30 students from class X SMK majoring in Computer and Network Engineering department. Generally, demographics of the participants can be seen in table 2. The Information asked for the participants were age, ever studied CT, ever learnt programming, time of playing games in a day, and

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had they ever used a VR device before. It can be seen that the ages were 14-16 years and 50% of them had studied CT. Most of the participants had also studied programming (60%), and 40% had never. Most of them are playing games in a day less than an hour (40%). Regarding to the last question, whether they ever used a VR device or related, 63.2% stated ever. These basic questions were asked to obtain information on how far the participants intersected with the research topic taken, including CT, games in general, and VR devices.

RESULT AND DISCUSSION

A. VR Game Application and its Gameplay

The VR-based educational game for learning CT was developed on the Android operating system. The VR device used in this study is a VR box with the Shinecon 6.0 G04E Stereo brand which is equipped with a headset to make it easier for players to listen to sound or music contained in the application. An external controller connected to Bluetooth is added to make it easier for users to explore every corner of the virtual room available in the VR game application. This device included to the low budget category because in terms of price it is very affordable.

In accordance with the design that has been designed as described in the methods section, this VR-based educational game for learning CT consists of two main scenes, namely the lobby scene, and the game scene. The lobby scene is the room where players can get information about the game to be played and the place to determine which game level to choose, namely 4 levels. Meanwhile, the scene where the game is played is the room where players can act and explore completing the tasks contained in the game. In this room players are going to learn about CT concepts by playing game or learning by playing.

Figure 5. Example mission of the game

Completion of the tasks or missions must comply with the game rules, otherwise the player will be declared as failed and unable to complete the mission or game over. Figure 5 is an example of a mission that must be completed so that the players said to be accomplished properly or completed. The mission explains that players have to develop a path like a bridge according to the map or visualization displayed on the screen. To create a path, the players have to give a "command input" on the provided place in the game.

Figure 6. Interface of command input

The user interface (UI) of "command input" is shown in Figure 6. The numbers imply sequence of steps that will be executed by the game system. Each sequence has a choice of commands, namely straight way, right, and left, specifically at level 1 and 2. Meanwhile for level 3 and 4 will have loop options that allows players to repeat commands without having to construct several arrow. Lastly, if the player is sure about the choice of sequences, the player can be running the program via execute the button. But if the player does not really sure about the choice of steps and sequences, players can press reset button to reconstruct the sequences and steps. This sequence of steps is common in programming environments. Thus, players can practice one of CT's abilities, namely algorithm design.

Figure 7. Tasks accomplished

With this game, players can learn about decomposition when the game tasks accomplished. Players will think that the tasks can be broken down into smaller parts to be tackled, for example making the bridge paths predictable in each direction, namely straight, right, left or looping. The small parts that have been broken down will make certain patterns so that players can practice to recognize patterns.

From the patterns, players will determine which ones the priority tasks that should be tackled and which tasks that can be unprioritized. This is where players will practice learning abstraction or sorting out the tasks that must be finished or ignore it. When the game is over, a recap of the steps that have been created will be displayed and players can proceed to the next level as shown in picture 7.

B. User Testing and the analysis

After finishing the development of prototype and its functionality, user testing was carried out with participants to obtain responses about the game. Figure 8 is an example of user testing conducted to the participants. It can be seen that two participants wearing VR devices and holding external controllers. They are playing and trying to complete the required tasks that has been designed in the game. They look focus on the game by trying to complete the provided tasks and really enjoy the game. The evidence is when someone is asked, they did not give response until patted first.

Figure 8. User testing of VR game application

After completing the VR game, participants were given a questionnaire that should be fill out about what they felt while playing the game. Cronbach's alpha reliability test is used to examine the internal consistency of the questionnaire. Meanwhile, to test the level of reliability of the relationship among statement items, Pearson correlation analysis was carried out. The significance level used for this test is 5% and the minimum Cronbach's alpha score as an accepted value is 0.6. After being processed using a data processing application, the results shown in table 2.

From the test results presented in table 2, it can be seen that all of the question items given were valid. This is because the score of each item is above the rtable (> 0.361). Meanwhile, the Cronbach's alpha score for each aspect is also reliable because all scores are more than 0.6. The scores for perceived usefulness (PU) and perceived ease of use (PEU) are 0.714 and 0.614, respectively. It means that PU and PEU are reliable. Meanwhile, the attitude toward using (ATU) and Intention to Use (ITU) scores were 0.754 and 0.882, respectively, which stated that ATU was reliable and ITU was very reliable.

Table 2. Reliability and validity test results

Aspects	Item	*Correlation coefficient*	*Cronbach's Alpha*
Perceived usefulness	PU1	0,871 (VALID)	0,714
	PU2	0,887(VALID)	
	PU3	0,609 (VALID)	
Perceived ease of use	PEU1	0,852 (VALID)	0,614
	PEU2	0,480 (VALID)	
	PEU3	0,884 (VALID)	
Attitude toward using	ATU1	0,829 (VALID)	0,754
	ATU2	0,912 (VALID)	
	ATU3	0,704 (VALID)	
Intention to use	ITU1	0,903 (VALID)	0,882
	ITU2	0,833 (VALID)	
	ITU3	0,958 (VALID)	

Based on the processed data, it can be interpreted that the participants feel if the VR-based game application is easy to use and has benefits. In addition, when viewed from the ATU aspect, participants also feel that learning CT using VR-based game is fun, interesting, and very suitable. Meanwhile, when viewed from the ITU aspect, participants feel that they are intended to learn CT again using the VR-based game application next time and really like game-based learning approach like this way.

Viewed from the conceptual framework, PU and PEU aspects of this VR-based game have a positive correlation with ATU. It means that the ease of use the application and the benefits obtained from using the game VR have affects to the behavior of participants. The easier and more useful that is felt by users, their attitude is also positive as well. Then, the ATU has positive correlation to the ITU aspect. It means that the positive attitude of users towards VR-based game applications for learning CT made them having a tendency to reuse this application again. Overall, it can be said that the low-budget VR game application that has been developed is easy to use, has benefit of learning CT, and users willing to reuse it in another time.

Even though overall evaluation has a positive response about the VR game application, some users felt that they have a little bit headache like car or motion sickness at the first time of using a VR device. These unpleasant experiences like motion sickness often experienced by VR users who have never using it before, because it takes a little adaptation to get used to the game environment which has a 360^0 perspective. However, after for a while of using the VR device, they no longer feel dizzy, and even more enjoy to the game and the environment generated in the game application. Some of the participants even wish that the use of VR applications like this could be applied to other lessons so that they would get better and more enthusiastic experiences.

CONCLUSION

Based on the data collected and analysis that has been carried out, it can be concluded that this low-budget VR-based educational game application has advantages and ease of use in learning CT. These factors of ease (PEU) and usability (PU) influence to the attitudes and behavior of users (ATU) towards the VR game application that make them intended to reuse it on another occasion. Some users even wish that this educational game-based learning approach using VR devices can be applied to other subjects, so that students can get different experiences while the teaching and learning process is carried out.

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