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Mobile Application: Learning Basic Mathematics Operation using Augmented Reality

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ABSTRACT

At school, students must learn mathematics not only as a formality to participate in exams, but also to use their mathematical knowledge to solve problems in their daily lives. When students deal with numerical information, they tend to have a negative feeling or fear, and this is known as mathematical anxiety. The project aims to develop a mobile application that integrates augmented reality technology into mathematical education and to evaluate the technological acceptance of the mobile application. This mobile application is reviewed and tested by 23 end users, most of whom are educators and parents. By using Technology Acceptance Model (TAM), three attributes were measured. The attributes include perceived as useful, user-friendly and intended for use. Based on the results, it can be concluded that the educators and parents are satisfied with the mobile application. For future work, the research recommends adding a variety of exercises with diversifying forms of questions with answers in the mobile application. It is further recommended that the augmented reality output to implement a 3D modeling design to project better virtual images.

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1.0 Introduction

Mathematics is a fascinating subject, and through learning and acquiring math knowledge, it can solve problems in our daily lives, such as counting money and calculating distance. In other words, mathematical knowledge is very beneficial to all of us because it provides vital skills for children's lives to adults in all walks of life, from primary school to university life. However, the current scenario is as, in primary and secondary education, the most frustrating subject for students in mathematics, and has the highest percentage of unqualified students among all subjects in school [1]. Meanwhile, at the university level, it is reported that 90 students in applied science from a

university in Tapah, Perak, were failing in the pre-calculus subject due to tests and mathematical anxiety [2]. So, in this situation, some alternatives may solve this problem. Based on the report from Kementerian Kesihatan Malaysia in “Pelaporan Pentaksiran Sekolah Rendah 2019”, primary school assessment test (UPSR) in 2019, 30.23% of students achieve a minimum of D grade for the mathematic subject. The student gets at least 1D in any subject and can become a problem that can be highlighted in the acquisition of mathematics. In the acquisition of mathematics, it is believed that teachers' pedagogical choice is an integral part of learning. Teachers are no longer expected to adopt a traditional chalk-and-talk approach but to empower a teaching pedagogy that is student-centred and joyful learning.

Pedagogy is a process of teaching and learning that uses art and science to deliver content. The means used are literacy, information, media and technological skills in teaching and learning, contextual teaching across disciplines, collaborative learning, project-based learning, problem-solving skills, transparent assessment and thinking skills. The pedagogical approach is an essential element in ensuring that students can master the content of the syllabus. There are four main categories of pedagogical approaches: behaviorism, constructionism, social constructionism and liberationism.

A behaviorist pedagogy uses behaviorism to inform its approach and learning style as teacher-centered and usually uses direct instruction and lecture-based lessons. An example of a behaviorist would be the research carried out by Rodriguez, which involves x-MOOC, an open online course that addresses learning, video conferences and weekly assignments [3]. Constructivism is a concept that people learn from their experiences and reflections. Constructivism is also a process of presenting a global concept of emergence relevant to the student in posing and directing in their questions to figure out the subject material [4]. Social constructivism can be considered a mixture of two precedents: teacher-guided and student-centered. Social constructivism is also the primary theoretical challenger to recognized perspectives surrounded by the discipline of international relations [5]. The social constructivist perspective is that human learning is constructed, and knowledge is constructed through social interaction with others and is shared and not an individual experience. A liberationist pedagogy is where the student's voice is placed in the centre, and democracy is placed in the classroom. Constructionism is an appropriate pedagogical approach in this project because the student can acquire knowledge and reflection of the mobile application.

Today, education and multimedia interact when there are many multimedia games, stories and activities that are used in the classroom. There are few definitions of education: 1) students who enjoy the media using a multimedia platform containing a combination of the multimedia element [6], and 2) education and entertainment (edutainment) combine [7]. Edutainment is the teachers’ new pedagogical model promoting active social learning. Edutainment is media designed to educate through entertainment [8]. Edutainment can focus on learning and memorizing facts, and it works well to teach lower-order thinking skills [9]. Many educational systems around the world use edutainment, an interesting form of education [10]. Rapeepisarn, Wong, Fung and Depickere claimed that there are two categories of edutainment that is (1) interactive, also called participatory, and (2) non-interactive or spectator [10]. Interactive is a type of edutainment in which children can play and contribute to the learning processes of game type. Examples of activities related to interactive learning processes include video games, puzzles, role-playing games, etc. While the non-interactive type of educational activities requires students to sit and do self-exploration and discovery, such as visiting the zoo, museum and science exhibition. Affirmatively, to support students' mathematical learning, the edutainment pedagogical activities which are interactive must be adopted in the mathematical learning process. Therefore, this research has motivated the development of a mobile application that integrates the technology of augmented reality into mathematics education. Perhaps it will become a solution to help students enjoy and learn math.

2. Literature Review

Malaysia has a centralized curriculum that integrates knowledge, skills, responsibility and ethics, focusing on the development of a balanced individual, and its curriculum covers a wide range of subjects in five categories: languages, arts, sciences, Islamic and moral education, design and technology [11]. Mathematics is part of the science category. There are four domains in mathematics

learning: Numbers and Operations, Shape and Space, Measurement, and Statistics and Probability. The basic mathematical operations are addition, subtraction, multiplication and division for figures and aspect operations. The main goal of mathematical learning is to develop problem-solving skills through the application of mathematics. When students learn mathematics at school, they can use their mathematical knowledge in everyday life. One can say that it is almost impossible if life without mathematics.

One of the means which has a positive impact on teaching and learning is the use of mobile applications [12]. For the mobile application to have a more in-depth functionality that can attract students' interest in exploring and acquiring knowledge, the technology of augmented reality can be added to the mobile application [13]. The augmented reality is the interaction of overlaid audio, graphics, text, and other visual elements in a real-world environment displayed at that time [14]. Augmented reality was a popular news topic for the past year because of the apps called Pokémon Go! that became famous in 2016. The implementation of augmented reality (AR), combined with print resources in educational contexts, has gained popularity in the research literature and business industry [15]. The common feature of augmented reality can be classified into three aspects: a combination of reality and virtual reality, interactive in real-time, and the register of dimensional scenes [16]. The interactive printing system as a mediator between the user and the content when markers like QR codes have recently been essential. This stage of the process has shown a negative impact on the user's experience [17]. Today, there are new software applications on mobile devices that no longer need markers to activate the content, but rather recognize the layout and design of the page as a whole to identify an interactive document [15].

Augmented Reality is part of multimedia, and all these multimedia elements are possible to be integrated into the technology of augmented reality: text, art, sound, animation and video [18]. Multimedia is delivered electronically or digitally to the user. Multimedia has strong interactivity features, good visibility, broad content and strong interest. These multimedia features have introduced new changes in educational circles and have become effective tools for teaching and learning activities, including mathematics [19]. The appropriate multimedia element used in the mobile application will produce an organized lesson [19] and will develop comprehensive skills for students to understand the subject they are learning. Students are immersed in the situation, actively participating in-class learning, so that they are engaged in multimedia teaching and familiar with the device's application [20].

3. Research Method

The process to achieve a positive outcome of this project requires a specific planning phase. Figure 1 presents a research model for this project which applies the Agile model. The model used in this development methodology is the agile model. The model includes five processes: planning, design, analysis, implementation and testing. The agile model is easy to adapt when some requirements change during the process. The advantage of this model is to optimize and improve the development of the process. Furthermore, the agile model can easily identify the problem and defects. In the test phase, the Technology Acceptance Model (TAM) was used as a guide for the production of a questionnaire to assess the level of acceptance of students and teachers for the proposed mobile application. TAM was selected because it remains the most widely applied theoretical model in the IS field [21] as well as mobile learning (M-Learning) [22].

Figure 2 illustrates the system architecture of the project. First, the camera functions as the input of the video stream to capture the image. The next step is image capturing, which analyzes each image of the video. In this process, it is generating the binary image. The source of the image capture is from the mathematics textbook, produce by the Ministry of Education (MOE). This process then proceeds to image processing. Image processing is the binary image that is a process that uses image processing to detect the marker. This process is able to detect the AR marker to determine the position. Tracker is the next process in the system architecture. In this process, the tracker acts to calculate the relative pose of the camera in real-time. At this stage, the input image for the target that needs to be tracked is uploaded. Target resources can be accessed through the mobile application via a destination manager that uses the web service or downloads from the target manager to be bundled with the mobile application. Rendering is the next step in the system architecture, which is to calculate the pose from tracking. The rendering process then joins the original image and virtual components by calculating the pose and renders. Finally, the augmented image displays the screen of the mobile device.

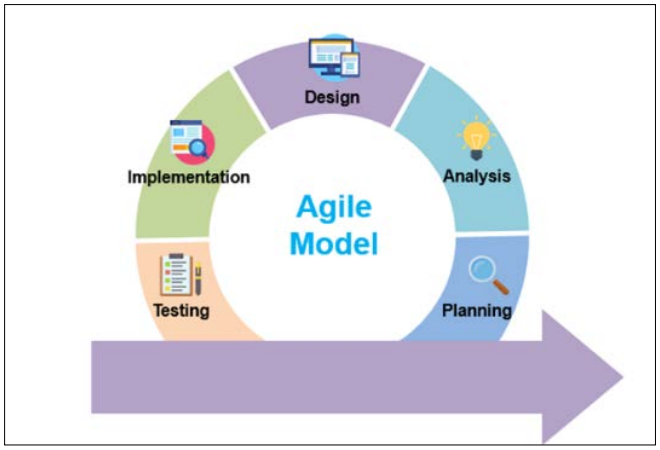

Figure 1. Agile Model

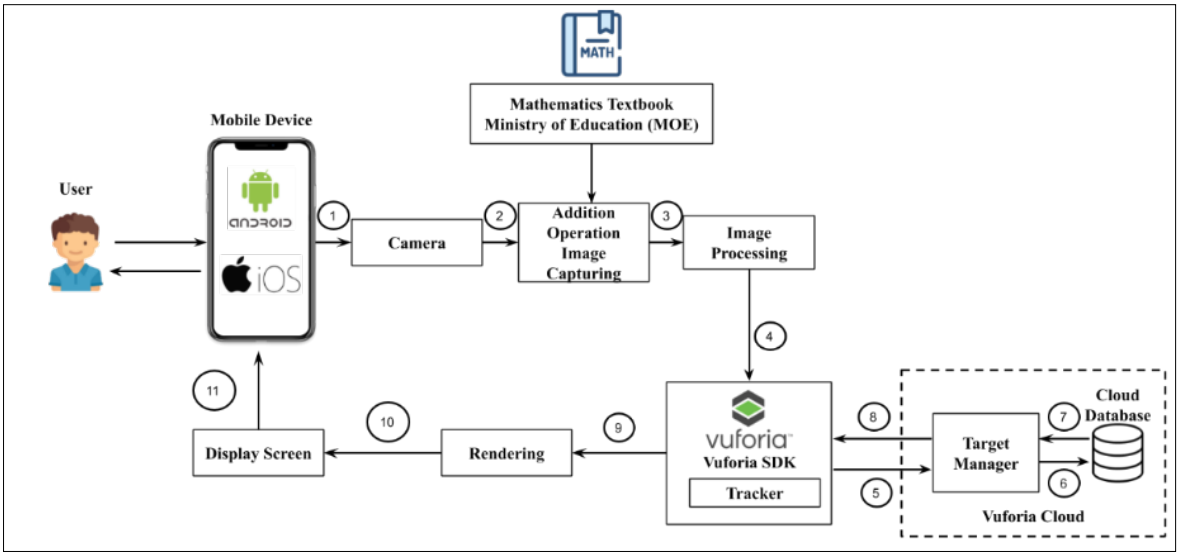

Figure 2. System Architecture

4. Project Design and Implementation

The mobile application is the central part of the project. This mobile application is the one used by end-users. The main features available are the ability to scan the AR marker, play and pause the video, and do mathematics exercises. Table 1 presents the interface of the mobile application.

5. Results and Discussion

5.1 Technology Acceptance Model Survey

The user's acceptance model was carried out to determine whether this mobile application can be used by the end-user and to assess the end user's satisfaction with its application. A total of 23 respondents who were parents and educators participated in the 2-week testing process, the technology acceptance model consists of three sections: perceived to be useful, perceived to be user-friendly, and intended to be used.

5.1.1 Demographic Information

This section will collect information on the respondents. Table 2 and Figure 3 show a summary of the total number of respondents by category. Based on the results obtained, the majority

of them are parents, who are 15 respondents and have contributed 65% in the pie chart. Then, 8 of the respondents contributed 35% of the educators.

Table 1. The interface of the mobile application

Interface	Features
	There are three buttons on this page, which are "*Mula*", "*Muat Turun Bahan AR*", and the exit button. The "*Mula*" button will navigate to the main menu page, and the "*Muat Turun Bahan AR*" will navigate to a website that has a list of download material of the Augmented Reality marker. Then, the exit button, which is in the upper right corner of the page, will lead to an exit page.
	For this interface, there are four operations that users want to learn, such as addition, subtraction, multiplication, and division. Based on the literature review, it mentioned that mathematics operation is one of the areas in mathematics, which is number and operation. There is a back button to allow users to proceed to the start menu and also an exit button for users to exit the application.
	Based on the screenshot, it is the process that instructs users to scan the marker. Instructions will appear when the marker is not detected. There are two buttons on this page, for users to do the exercise about a particular topic and an exit button for users to exit the application.
	The instruction disappears because the marker is detected. When the marker is detected, three buttons appear on this page, which are play, pause, and stop. The video will appear when the users scan the AR marker. The multimedia element that is used is audio, video, animation, text and image
	In the exercise section, there is the main part of the page and the question part. The main page instructs users to do this exercise.
	As for the question, the users will answer the question in multiple choices. When the response is correct, the right sound will appear and the score will be added. A song will be played on this page. If the response is wrong, the wrong answer will disappear, and the score will not be added.

Table 2. Total number of the respondents by category

Category	Count
Parents	15
Educators	8

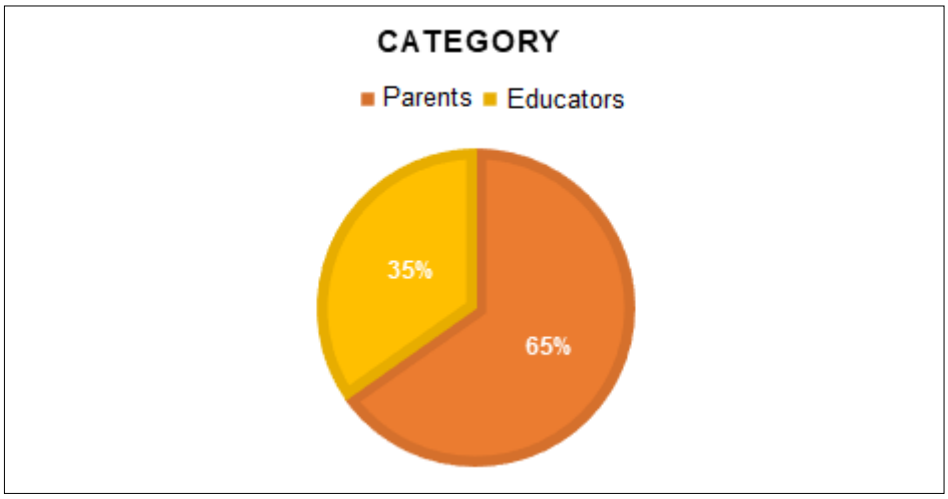

Figure 3. The percentage of the category

5.1.2 Perceived to be Useful

This section of the technology acceptance model aims to identify the perceptions of the users of this mobile application if it is useful for math learning. There are three questions in this section. The first category is whether the mobile application is perceived to be useful for educators. The results are shown in the bar graphs below in Figure 4.

In the first question, 5 respondents strongly agreed that the use of this mobile application can enhance teaching performance. Then, almost all respondents (8 respondents) strongly agree with the second question that is, this mobile application is useful for the class session. The third question that is using this mobile application makes it easier to catch individual students' needs. In this question, 4 respondents agree with this question, and there is only 1 respondent who strongly disagrees with this question. The results of this section that are perceived to be useful are acceptable, and educators are satisfied.

The following category is intended for parents. The questions were quite different from educators, where the questions are focused more on the kids. Approximately 9 respondents strongly agree that using this mobile application can enhance their children's learning performance. Interestingly, 10 respondents strongly agree that this mobile application is useful for their children's learning sessions. The last question is whether using this mobile application makes it easier to catch individual students' needs in understanding basic mathematics operations. Most respondents agree very strongly with this question. The conclusion in this section that is perceived as useful is acceptable, and parents are satisfied with it. The results were visualized in the bar graphs below in Figure 5.

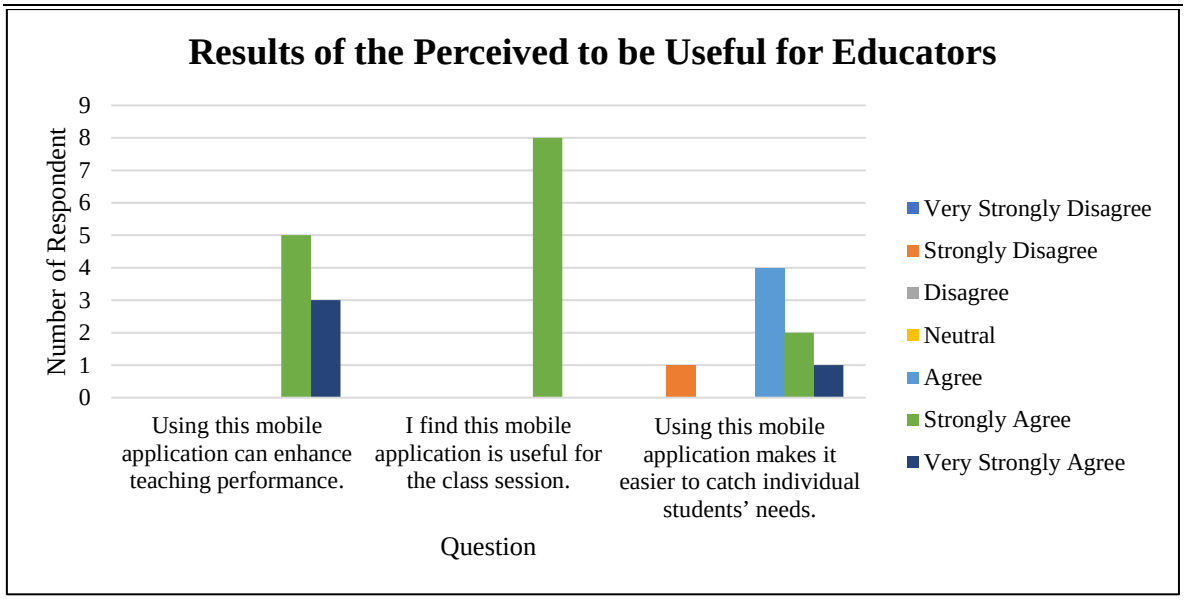

Figure 4. Results of the Perceived to be Useful for Educators

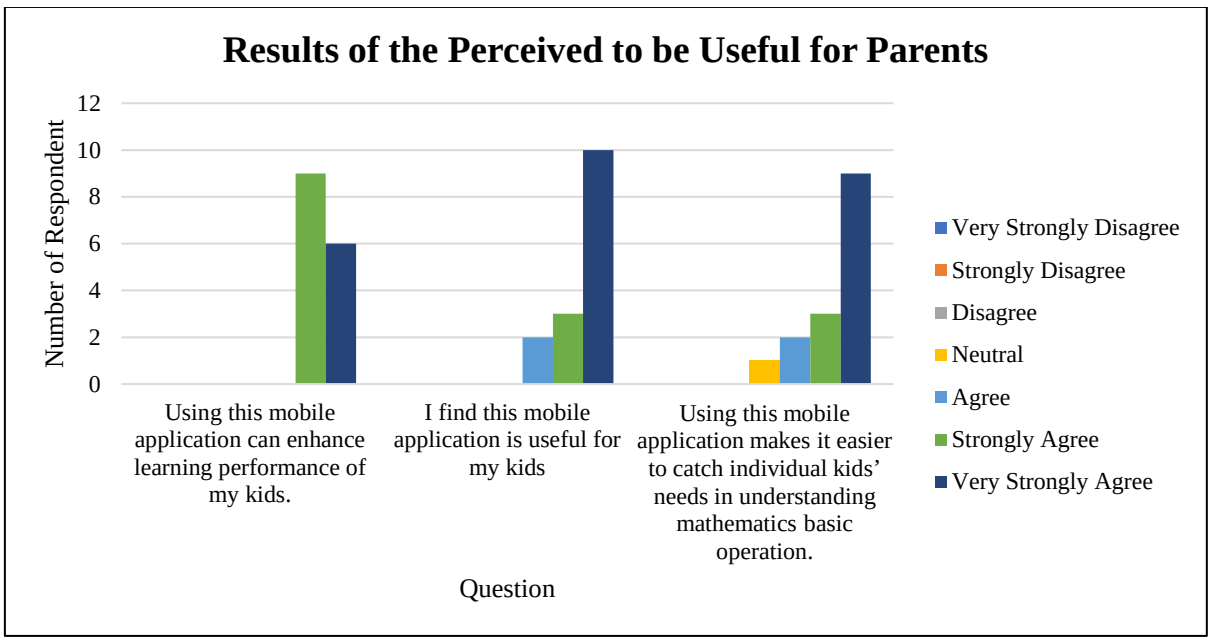

Figure 5. Results of the Perceived to be Useful for Parents

5.1.3 Perceived to be User-friendly (Ease of Used)

As for this category, most respondents strongly agree that this mobile application can be easily applied in the classroom. The respondents also strongly agree with the design used in this mobile application, which is easy and understandable. The number of respondents who strongly agree is 4 respondents. 4 respondents strongly agree with the story in the video of this mobile application is easy to understand. There are also 3 respondents who strongly agree and 1 respondent who is neutral in this question. Last but not least, there are 4 respondents here who strongly agree with this question, which is the use of mobile applications is more flexible to teach than a traditional one. The results in Figure 6 show that the mobile application is user-friendly are acceptable, and the educators are satisfied with the ease of use it.

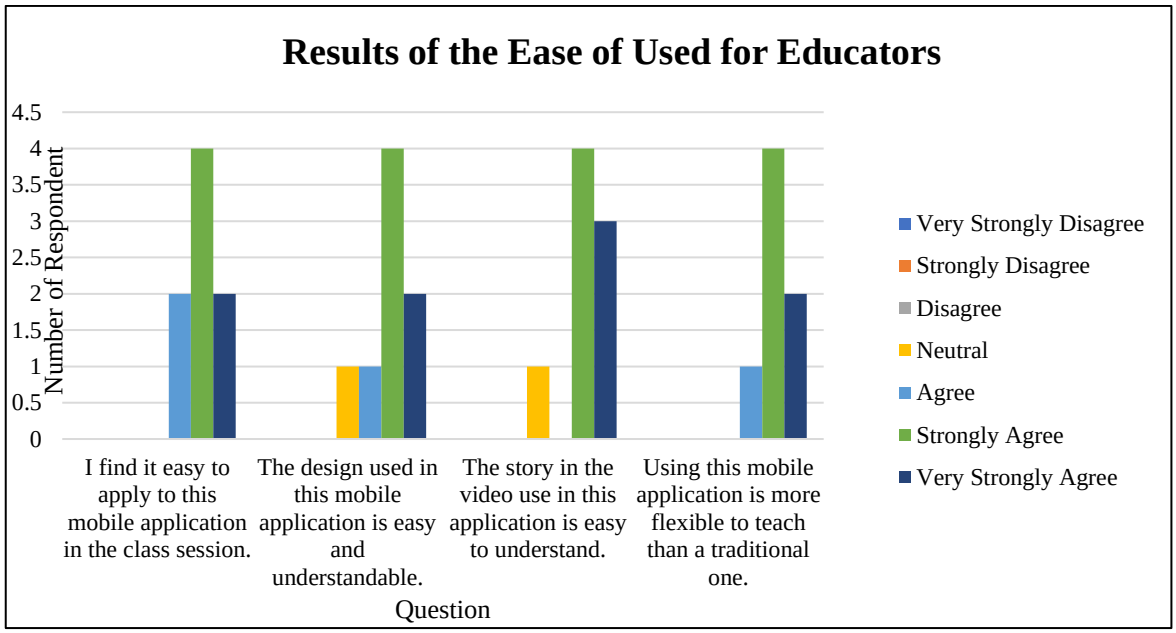

Figure 6. Results of the Ease of Useful for Educators

The next category is the ease of use for parents. For the parents, the questions are quite different from that of educators who focus more on their children. The results were presented in the bar graph below in Figure 7.

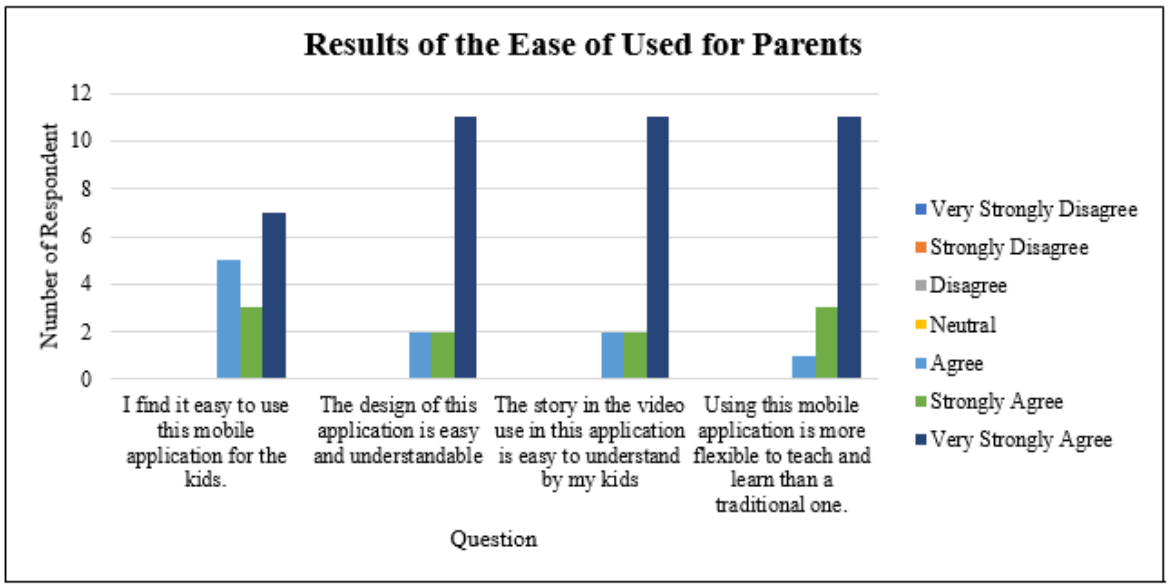

Figure 7. Results of the Ease of Useful for Parents

Most respondents agree with all questions raised with 8 respondents agree very strongly with the statement that this mobile application can be easily applied in the class session. 11 respondents very strongly agree with the design used in this mobile application, which is easy and understandable. In addition, 11 respondents also very strongly agree with the question that is, the story in the video of this mobile application is easy to understand with 2 respondents strongly agree and 2 other respondents agree with that same question. Last but not least, 11 respondents strongly agree with this question using mobile applications is more flexible to teach than a traditional one. The results of this section that are user-friendly are acceptable, and the parents are satisfied with this.

5.1.4 Intention of Used

In this category, it is interesting to note that most respondents strongly agree when different questions are asked. 4 respondents strongly agree when the question tending to use this mobile application for the class. For the next question, which is the user interested in encouraging their friends to use this mobile application for the class, 6 respondents strongly agree and the other 2 respondents very strongly agree. Most respondents strongly agree that they love using this mobile application to teach students. In the next question, which is that students love to learn using this mobile application, the same value was detected for the number of respondents between strongly agreed and very strongly agreed was detected which is 3. Finally, most respondents strongly agree that this prototype is appropriate for other operation, such as subtraction, multiplication and division. The results of this section, which are intended for use, are acceptable, and the educators are satisfied. All of the results discussed are presented in Figure 8 below.

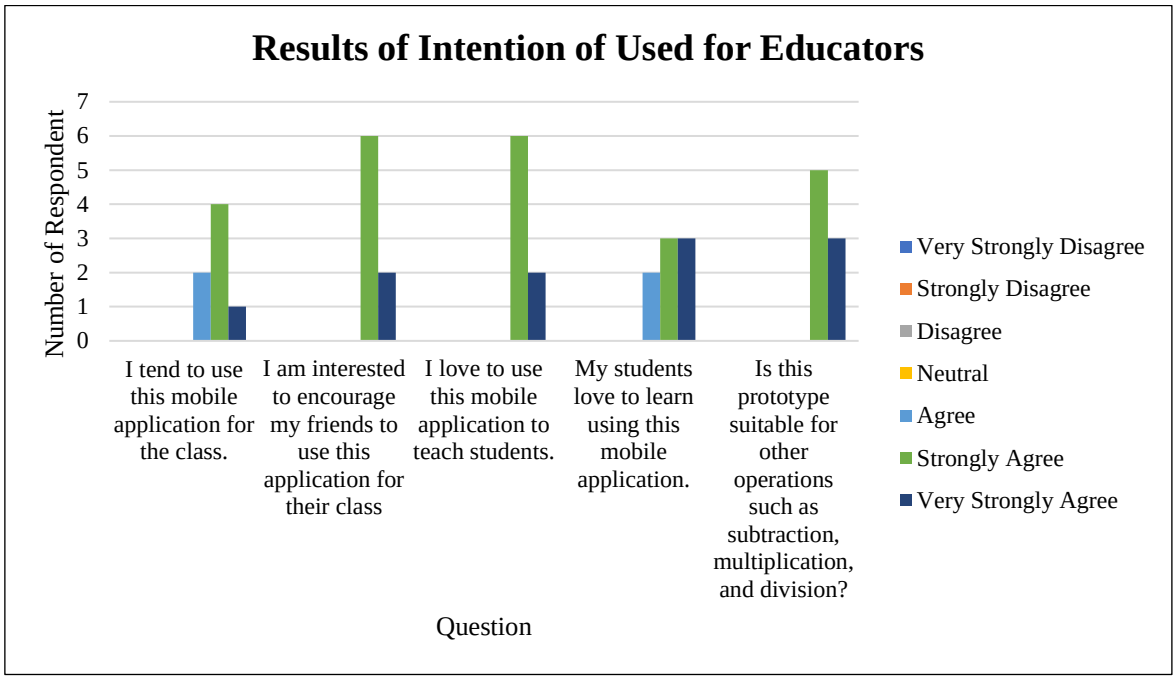

Figure 8. Results of Intention of Used for Educators

The next category is Intention of Used for the parents. In this category, the question is quite different from that of the educators because the focus is more on children. The results are shown in the bar graphs below in Figure 9.

Interestingly, 10 respondents strongly agreed to encourage their friends to use this mobile application for the class. For the next question, which is that the respondent tends to use this mobile application for kids at home, 8 respondents very strongly agree and 7 respondents strongly agree. 9 respondents responded very strongly that they like to use this mobile application to teach their kids. In the next question, which is that your children love to learn using this mobile application, most of the respondents to this question agree very strongly with 10 respondents. Finally, this is the question that gets the largest number of respondents with 11 respondents very strongly agree that this prototype is suitable for the other operation such as subtraction, multiplication and division. The results of this section that are intended to use are acceptable, and parents are satisfied.

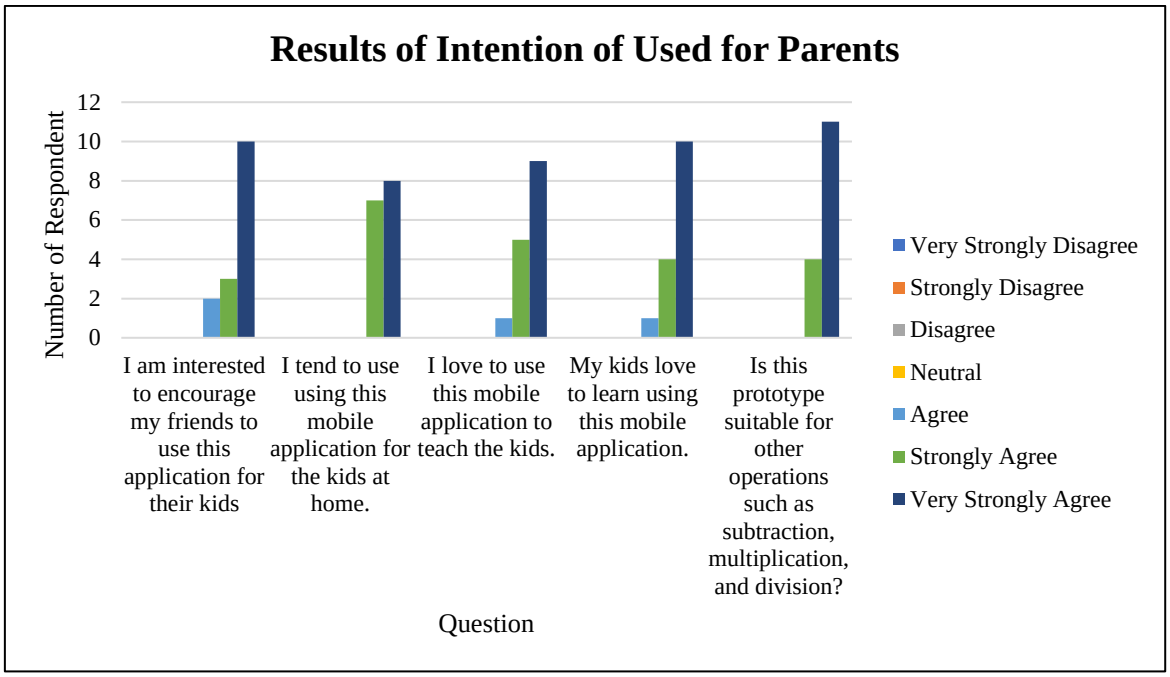

Figure 9. Results of Intention of Used for Parents

5.2 Respondents' Comment and Suggestion

This section emphasizes the comments and suggestions of respondents. In the last question, using the technology acceptance model, the questionnaire covers comments and suggestions from respondents. This question is very important because it is for the recommendation and the future work of this project. Table 3 shows the feedback and suggestions that have been tabulated.

Table 3. Respondents' comments and suggestions

Respondent	Comments and Suggestions
1	This application is suitable for primary school. However, even more, interesting if there is output in 3D. If there is an improvement, it can not only attract students or children to learn, but also adults are interested in this application.
2	Very interesting, but only the background voice needs to be clear again, whereas the video quality needs to be improved to be more interesting.
3	Diversify forms of questions. Great for kids to use an application like this when using a smartphone.
4	Include answers to the practice questions
5	Use colors or patterns that can give more interest to children

Table 3 contains 5 suggestions and comments from respondents. One respondent suggested using 3D as an output of augmented reality because it's much more interesting. Then there is also another suggestion that the background voice and video must be clear. In addition, one of the respondents suggested diversifying the form of the questions because she believed that a type of question was not sufficient for their children. There is also a suggestion that includes answers to the question of practice. Finally, the last respondent stated that the use of colors and patterns could give more interest to children. Comments and suggestions from respondents were evaluated for the implementation of future work.

6. Conclusion

Learning basic mathematical operations using a mobile application that applies augmented reality is perceived as very successful with appropriate development and designed that was able to help the acquisition of mathematical learning. The mobile application has been created where the user will watch a video via Augmented Reality. The project has undergone a few exercises. The exercise is divided into three stages: Easy, Medium and Hard. Although the development of the project has succeeded, and all objectives have been achieved, this mobile application has several limitations. First, computer performance is used to develop this mobile application by applying the augmented reality, where the Unity engine requires a higher processor and memory for the game to create and develop. Subsequently, in some Android devices, performance may not be smooth when running apps due to the different specifications of the Android device.

Several recommendations on the future work of the project were made after evaluation of the test results and project limitations. The first recommendation is to develop a better computer with higher memory and processor. Using a better computer can facilitate the process of editing and developing this mobile application. In addition, adding multiple types of exercise in this mobile application so that the user can do more practice makes it more understandable. Finally, in the future, the output of augmented reality should be 3D use because it can be much more interesting. With regard to the exercise section, various forms of questions should be introduced to ensure that children strive, through the questions, to use alternative methods and to include the answer to the children to be reviewed.

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