Cube's Volume: A Game- Based Learning involving Volume Visualization for 4th Grade Students

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Abstract—Under the new K-12 program of the Department of Education (Philippines), the subject of Geometry is now being taught in primary schools. Because the topic volume is under Geometry, it will be also taught to elementary students, particularly in Grade 4. This study aims to propose an Android game-based learning that tackles Volume Visualization and it intends to make the game interactive to students, educating, and fun. It also aims to integrate aspects of Filipino society into the game. This research can also complement existing methods that are being used in teaching. The mobile game was developed using Unity, a cross-platform game engine that uses C# as the programming language. The results shows strongly for the application's functionality. Furthermore, all practical and academic implications are discussed below.

Index Terms—cube, mathematics, mobile game, volume visualization

I. INTRODUCTION

The Philippines' K-12 program, enacted by the Department of Education in 2013, states that Grade 4 learners should be able to show skills that understand the basic concepts of Geometry that involve numbers, shapes, basic algebra, simple data sets and structures, probability, critical thinking, solve complex problems, logical deduction, and decision making that relates to real life situations [1], [2].

From 1995 to 2003, the Philippines participated in the Trends in International Mathematics and Science Study. The country lagged behind others as stated by their reports [2]. But recently in 2015, the results of the International Math Competition in Singapore showed that the Philippines bagged 2nd place, contrary to the results of the TIMSS [3]. It means that the quality of education in the Philippines has greatly improved [4].

Technology is now an improving factor in education [4]. Anyone, even students, can now access supplemental information through the internet such as tutorials and ebooks. Some are free and some are paid. Private schools in the Philippines have agreed to provide students, particularly in kindergarten, primary and secondary levels, as an aid in learning [5].

This study intends to be a supplement in learning for elementary children. "Cube's Volume" is a game-based Android application which is about volume visualization and how volume works.

II. REVIEW OF RELATED LITERATURES AND STUDIES

Games can be defined as playing a competitive sport that is followed by rules and end in a scored result [6]. The purpose of well-designed games in classrooms serves two purposes. First is games should be fun, and second, they should provide a way to extend practice outside a lesson [7]. A lot of designers, researchers, workplaces and educational institutions are now stuck in a dilemma on how to get children, teenagers, and young adults, to learn and master a game that has both good gameplay and storyline [8].

Mathematics and its relevance to society are to solve complex problems, especially starting at elementary school. It is an important aspect of our everyday lives [9], [10]. At present, mathematics education should aim at students understanding the problem and solving it correctly [9]. It's learning approach should be integrated in a digitalized way [11]-[13]. Teachers, researchers, and many educators have been supporting and advocating the development of educational games [14]-[17]. There is a recently popular technique called "gamification" that uses ideas from game design to increase students' class participation and, more importantly, their learning quality inside the classroom [15]. Educational video games are now being used by some teachers in supporting encouraging students to use other educational software [11], [15], [18]. An educational game should emphasize primarily on storytelling elements, its design, and its effectiveness in the subject/topic that it is focused on [14].

Digital media is now the norm, especially in young children. (Christie and Johnson, 2009), wherein they

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exceed adults in their knowledge of it even before starting school [19]. There is a research study wherein it states that there are new ICT tools available that provide children learning platforms and other online services. This ICT tools also help them in learning new knowledge through activities that are related to real life scenarios [19]. Digitized educational activities that are properly designed can be a very useful and effective tool in learning [6], [13], [20]. Activities that are interactive can be helpful in children and it can also be a factor in their growth in terms of learning incentives and finally, in their right mental development for science and math subjects.

Students as early as kindergarten have now advantages in using mobile phones wherein they can access relevant information about mathematics which has new and attractive features [6], [19]. In a published study, it stated that Mathematics has a very high failure rate in the Caribbean. Therefore, a personalized, game-based learning mobile application has been developed in helping high school students to motivate in learning and practicing their Mathematics lessons. Additionally, it helps the students to easily explore the system via the personalization feature and it give recommendations to the student to particular features of the application. Additionally, the aspect of the game aims at making learning a less stressful process [21].

Analysts have focused their research on studying mathematics through the utilization of Mathematics [21]. There are a lot of advantages in the use of smartphones in the education process, such as inducement, encouragement, availability, user-friendly, etc. (Vavoula & Karagiannidis, 2005). Seldom are there game-based mobile applications that are about our aim. There is a game developed for the PDA back in 2003 which tackled on Geometry where the end-users were 6-year old kindergarten students. The study resulted in a good future where eLearning will be a norm [22], which can be observed today.

III. METHODOLOGY

This mobile game is part of a large game development project involving a non-government educational foundation, professional technological institution, and a network of elementary schools in the Philippines. The project aims to provide a set of mobile games for elementary students to enhance their academic performance on mathematics subject. This research has been conducted using the Waterfall method. Requirements were given from the organization and the design was submitted to them for approval. After implementation, verification can be done by the organization and the end-users. Also, this research used Unity, a game development platform using C# as the programming language and Inkscape, a free and open-source vector graphics editor in creating and editing the vital game assets and user-interface. This study involved a group of stakeholders from a private, non-government, educational foundation and grade 4 students from a public elementary school here in the Philippines.

IV. RESULTS AND DISCUSSION

The figure below shows the System Architecture of the game. The challenge mode is the Mathematical Skills Assessment of the game in which it tests the user's skills in answering the questions at a given amount of time. The Math Logic functions inside the Game Engine Framework where it defines the procedures of the topic especially Volume Visualization. Then it is all programmed and encoded to the Game Logic. Levels Two and Three are co-related to one another. The reasons are the Physics, Audio, and Graphics components are programmed to do their functions properly.



Figure 1. System architecture



Figure 2. Main menu

In the figure above shows the main menu screen that features the practice and challenge buttons. When tapped, the practice mode will take you to the story of the game in which Karl, the main character, will narrate the scenario.

In the scene above, it illustrates the game problem wherein Karl, the game's character, explains that he needs help in counting the volume of the cubes.



Figure 3. Game Story



Figure 4. Difficulty menu

The above figure shows the three difficulty options, namely the easy, average, and difficult modes.



Figure 5. Easy mode gameplay

The above figure illustrates the easy mode gameplay in which there are 3-7 combinations of cube stacks.



Figure 6. Correct answer

When you get a correct answer, a dialogue user interface will pop-up saying "Awesome!".



Figure 7. Incorrect answer

Else if you get an answer wrong, a dialogue UI will appear and say "Try Again". Also, the main character's

face will change whether you get the answer correct or not. The two dialogue user interfaces also show in the other two difficulty modes except for the challenge mode.



Figure 8 .Average mode gameplay

Fig. 8 shows the average mode gameplay wherein there are 6 - 10 combinations of cube stacks.



Figure 9. Difficult mode gameplay

Lastly, the difficult mode has 8 - 12 combinations of cube stacks.



Figure 10. Pause menu



Figure 11. Challenge mode gameplay

When the button that is highlighted above is clicked/tapped, a user interface panel will appear in which

it has three buttons. First, the "Main Menu" button will take you to the main menu. Second, the "Change Difficulty" button will take you to the difficulty menu as shown in Fig. 4.4. Lastly, the third button will take you to an another question.

Here, it shows the challenge mode where the only difference from the practice mode is there is a timer present and the two upper left buttons are now unavailable. In addition, the challenge mode comprises of 5 questions from the easy mode, 3 questions from the average mode, and 2 questions from the difficult mode, completing the requirement of 10 questions for the challenge mode. Also, the questions are in random sequence.



Figure 12. End game scene

Finally, the last figure shows the end game scene in which it illustrates a dialogue user interface. In the user interface, it tells the user's overall score and a button is present where it will take the user to the main menu.

Criteria	Mean	Interpretation
1.Functionality	4.63	Strongly
		Agree
2.Reliability	4.31	Agree
3.Usability	4.43	Agree
4.Efficiency	4.51	Strongly
		Agree
5.Maintainability	4.38	Agree
6.Portability	4.52	Strongly
		Agree
Total	4.46	Agree

TABLE I: SUMMARY OF THE SOFTWARE EVALUATION

In summary, the software evaluation indicates a strong perception among the respondents that the Cube's Volume mobile application is highly functional (4.63), reliable (4.31), usable (4.43), efficient (4.51), maintainable (4.38), and portable (4.52). Hence, the software evaluation receives an overall rating of 4.46 with an interpretation of Strongly Agree. Results indicate that the mobile game performs the volume visualization. Additionally, the respondent's game skills improve while after answering a question from the game.

V. CONCLUSION

This study aims to provide an educational mobile application that introduces volume visualization to public elementary school students. Based on our conducted research, there are limited works that are related to ours. Also, our findings showed that educational mobile applications and game-based learning have a significant impact on the education of children especially on the subject of mathematics. Nonetheless, this research has some recommendations to enhance the findings of this study including: (a) an iOS developed version of Cube's Volume; (b) more added features like new balls and containers, and (c) to represent a better visualization of volume using 3D animation.

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