Chapter in Book

Get The Prime AR – A Gamified Exercise

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Abstract: *The fundamental of an effective teaching and learning process is a successful communication between the teacher and the students. As communication is evolving rapidly in-line with the development of technology, it would only be logical for teaching to adapt those advancement so that it can remained relevant in today's society. One of the major changes in communication is the reliant on portable electronic devices especially mobile phone. It would not be a surprise if students treat those devices as if their appendages. Unfortunately, evidence showed that most of the screen time was for the purpose for leisure such as gaming. Realizing this, an attempt been made to gamify mathematics learning by utilizing communication technology through an augmented reality (AR) game known as "Get the Prime". This study is aimed to enhance students' performance in identifying one to two digits prime numbers through the AR game. The population of the study was Form 4 students and the sample was 68 students drawn from 2 classes. This study is a mix study. The quantitative data was obtained through quasi-experimental with pre and post-test design. Meanwhile, the qualitative data was obtained through a simple structured interview. The increment in the mean value was 31.62%. The paired sample T-test resulted in a mean difference of 1.591 ($p < 0.05$) and effect size of 0.516 (> 0.5) showed that there was a significant difference between the pre and post-test in students' performance. Based on students' feedback, they were motivated as they were competing which each another. "Get the Prime" is specially made to carter the needs of local students. As a self-developed product, it warrants the relevancy to the current syllabus and could be adapted for other subjects. Additionally, it can also be commercialized as free to play or as a premium product.*

Keywords: Mathematics education, gamification, prime numbers.

1. INTRODUCTION

In today's world situation, there are tremendous paradigm shifts at all levels of humanity; be it education, technology, economics and politics. One of the major catalysts of these shifts is the rapid growth of technology which changes the way people interact with each other. Postcards, snail mails and phone calls which were once the popular ways of communication have now become almost irrelevant to today's society. Text messaging, instant messaging, voice messaging, email and social networking are the new communication platforms to those who are born into the technology era (Cyr, Berman, & Smith, 2015).

Since teaching is a communication-based activity (MacGrath, 2005), technological advancement has affected the teaching and learning process. Ever since the process is shifting towards students' centered activities, technology in various forms has been heavily adapted to suit the needs of

students. From textbook to graphical textbook to computer animated slides are the current trends of education to boost the richness of students' learning experiences. Education is the students' experiences as a result of the learning processes (Kelly, 2009). Perhaps, this is the only way for education to remain relevant and also to fulfil the needs of today society.

Game-based learning has been gaining enormous attention from researchers (Qian, & Clark, 2016). Gamification has become a trend that had been implemented in various settings especially in the educational field (Pho, & Dinscore, 2015). Numerous studies have supported the effectiveness of game-based learning in enhancing students' performance. In education context, game-based learning is not as simply as creating games for students to play. It is an instructional design with learning activities which integrates concepts and guide students to attain learning standards. The effectiveness of game-based learning depends on the adaptation by the teachers. Therefore, it is crucial for teachers to select or develop suitable games for their students.

2. METHOD & MATERIAL

This study was a mixed study as it comprised of two phases. The first phase was a quantitative design which followed quasi-experimental because it attempted to determine the effectiveness of self-developed teaching aid known as "Get the Prime" in enhancing students' achievement in identifying one to two digits prime numbers. In order to identify the strengths and weaknesses of the teaching aid, the study then went into phase two which aimed to obtain feedback from students through qualitative design. Taking consideration into the time restriction and feasibility of the study itself, the qualitative design followed a simple structured interview. However, to ensure the reliability and validity of the data itself, triangulation was implemented in the structured interview.

The population of this study is Form 4 students from public school who study Mathematics and Additional Mathematics. The sample consisted of 68 male students. Students' achievement was obtained from two instruments, a set of test paper and students' scores from the "Get the Prime" itself. Meanwhile, phase two of the study used a simple set of questions to obtain students' feedback on the teaching aid itself.

The study began as teacher was teaching about prime numbers. The concept, ways to identify and uses of prime number in Mathematics were discussed in class. It was then followed by a test which attempted to determine students' achievement in identifying prime numbers. These scores would be used as the pre-test score. The intervention, which was a computer game known as "Get the Prime" was then introduced as replacement to the conventional exercises. Students' score obtained from the "Get the Prime" added with another test with similar difficulty as the first one was used as the post-test score. Paired sample t-test was performed using Statistical Package for the Social Sciences (SPSS) version 23.

One of the main reasons that motivate the development of "Get the Prime" is to create a game which is specifically designed for the local context which will warrant its relevancy and needs. As mentioned earlier, students cannot recognize prime numbers though they have learnt it. Therefore, this game is created to meet the learning standards of the students. It began as a computer only space shooting game without sprite. As the basic control had been coded, it was then developed into "Get the Prime" by adding prime and non-prime numbers. As for psychological factors, life bar was added whereas player would be penalized when they mistakenly get non-prime numbers. This acts as the negative reinforcement (Ormrod, 2014).

After few tests play by the developer, bonus sphere was added as the positive reinforcement. This bonus sphere when obtained would increase the life bar or if it is full, will give player bonus score.

Ammo bar was also added to promote strategic play which aimed to motivate students to identify non-prime numbers so that they can shoot it to convert into prime numbers.

After getting students tested the game, a local scoreboard was then added to promote competition among players. Finally, few adjustments such as two digits prime numbers, levels and ability to obtain better spaceships were added to attract students to play the game. It was then followed by optimizing the codes for both computers with Windows and smartphones with Android operating system.

There are some notable features of the game. Firstly, evolving ships were designed to capture students' interest. The ship will evolve to a bigger and more advance ship based on the score the players obtained (Figure 1). A bigger ship could move faster but the increase of surface area also means players need to be more careful to avoid non-prime numbers.

Figure 1. Type of spaceships.

There is also a bonus stage which can be reached upon filling in the "fever bar". In that mode, player will be temporarily granted the control of another type of spaceship. This is to motivate students to identify prime numbers correctly and consecutively.

Due to the potential and success of augmented reality (AR), attempt was made to utilize this into "Get the Prime". The rational of adding AR is to further attract students' interests in playing the game. Although some changes were made to the game, most of the psychological factors from the previous teaching aid are retained.

In the "Get the Prime" AR, there are stars labelled with prime number and non-prime number. Students have to tab stars which labelled prime number. A new feature which is the bonus multiplier was added as the positive reinforcement. This bonus multiplier was time limited and would further increase the score. It serves as a motivational factor that enhances students' reaction time to prime numbers. When students achieve certain level, yellow stars which labelled 2-digit prime numbers and non-prime numbers would appear. Purple stars would also be seen when students achieve higher level. As the game is self-developed, its difficulties of level may be adapted accordingly students' performance. For low-performed students, the time taken to tab one-digit prime numbers may be longer in order to suit students' level. Besides, the scores and penalties can also be adjusted and altered from time to time.

After getting students tested the game, an online scoreboard (Figure 2) was added to promote competition among players. The scoreboard can show up to top 15. It was then followed by optimizing the codes for smartphones with Android operating system. Figure 3 to Figure 7 were in-game screenshots.

Notable improvements of the game are online scoreboard, 3-dimentional game and AR enabled which based on preliminary data was able to significantly boost students' interests in playing the game.

In order to increase the availability of the software, the source code can be compiled into numerous platforms. For the purpose of this study, it had been compiled into android application package (apk) for Android operating system.

Figure 2. Online scoreboard.

Figure 3. Instructions.

Figure 4. Blue color stars (Level 1).

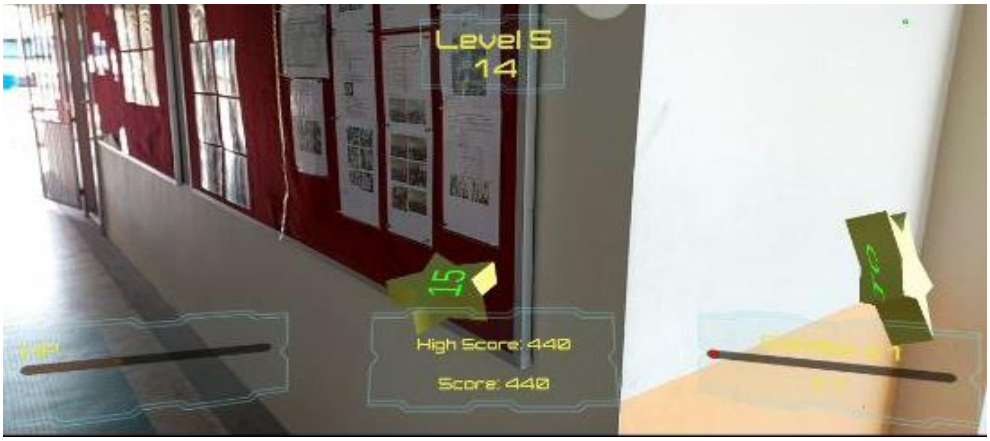

Figure 5. Yellow color stars (Level 2).

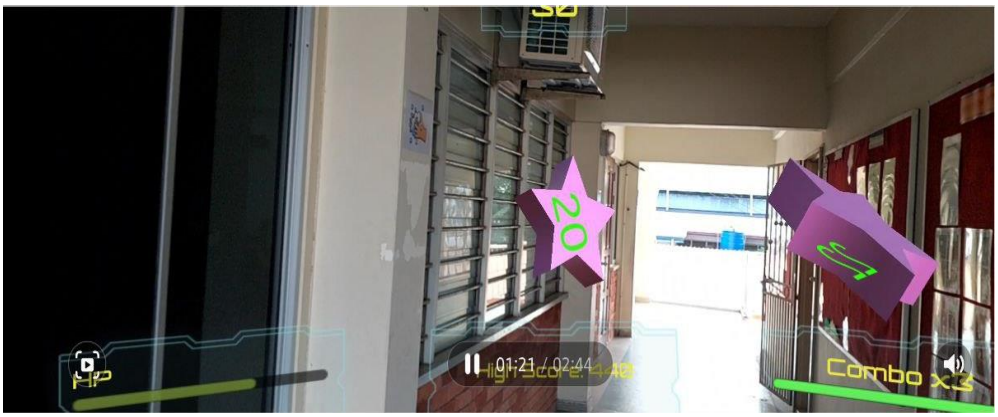

Figure 6. Purple color stars (Level 3).

Figure 7. End of Game.

3. FINDINGS

The findings of the study were analysed by using T-test (pre and post-tests), effect size and further supported by interview.

3.1 Data Analyses

The pre and post-tests results were analysed using Statistical Package for the Social Sciences (SPSS version 23). The table below shows the mean of the pre and post-test:

***Table 1**. Mean of Pre and Post-Test.*

	Pre-Test	Post-Test	Difference in Mean	Increment (%)
Mean	5.032	6.623	1.591	31.62

The mean value of the pre-test was 5.032 meanwhile the mean value of the post-test was 6.623. The mean value has increased 1.591. This indicated that students' performance has increased and it was a significant improvement as it increased 31.62%. Figure 8 shows the mean value of pre and post-test.

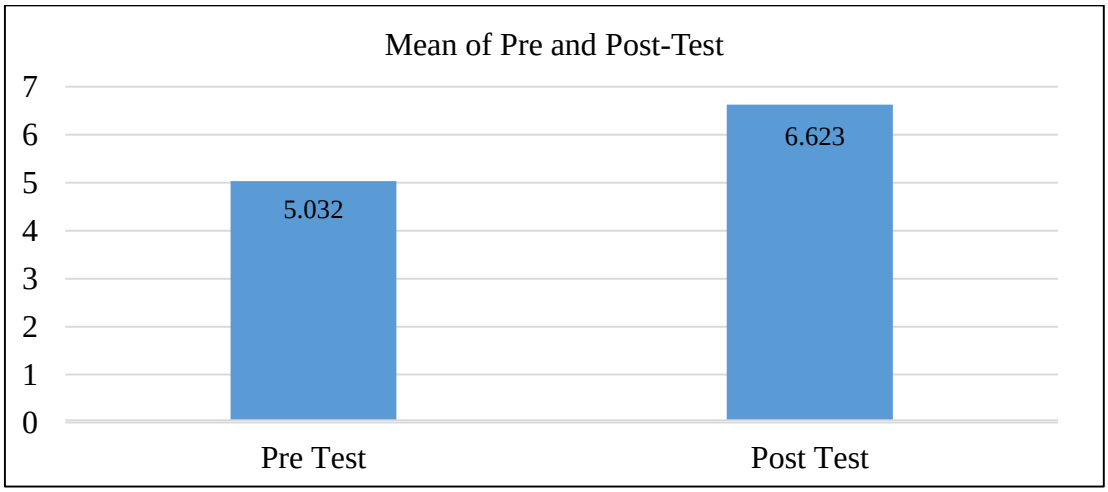

***Figure 8.** Mean of Pre and Post-test.*

Paired sample t-test was conducted to determine whether the effectiveness of self-developed teaching aid known as "Get the Prime" in enhancing students' achievement in identifying prime numbers. The findings were shown in Table 2.

***Table 2.** Paired Sample T-Test.*

	Mean	Sig. (2-tailed)	Effect Size
Mark Set 2 – Mark Set 1	1.591	0.046	0.516

Based on the mean values, it showed that students had increased performance in identifying prime numbers. Although the mean differences were not that high, it should be noted that it was statistically significant ($p < 0.05$) and the effect size (>0.5) indicated the differences were of educational important (Cohen, 2000).

Phase two of the study was qualitative, hence there no statistical analyses for this part of study. However, through interviewing three of the students with score ranging from low, intermediate and high, showed that they were interested in "Get the Prime". Mainly because they were actively engaged

in the game and the scoreboard motivated them to try to obtain higher score just to get the bragging rights.

On the other hand, students also noted that there were no variations in the gameplay. It had to be noted that this is by design as an attempt to avoid addiction in playing the game. Preferably, once the objective had been achieved, students would move on from the game itself.

4. DISCUSSION

The findings shown in Table 6.1 and 6.2. Based on the difference in the mean value (1.591), it showed that students performed better in the second set of questions. It was worth noting that the mean increased 31.62% from pre to post-test. Despite mean difference was not that high, it should be noted that it was significant (0.046) and the effect size (0.516) indicated the difference was of educational important. Therefore, it could be concluded students' performance increased after using "Get the Prime" game.

Based on students' feedback, they were interested in the game. Their feedbacks were reliable and valid because they gave similar responses when asked in different ways. This was done as part of the triangulation. More importantly, students reported that they get bored quite fast but this is actually by design to avoid addiction to game. Therefore, it was concluded that "Get the Prime" effective yet avoid the most common issue in gaming, addiction.

5. CONCLUSION

Prime numbers which are the basic in number theory plays an important role in certain mathematics learning area. Therefore, it is necessary for students to identify and recognize it. The purpose of the study is to determine the effectiveness of self-developed teaching aid known as "Get the Prime" in enhancing students' achievement in identifying one to two digits prime numbers. The results of this study showed that gamifying exercise on prime numbers through "Get the Prime" was effective in enhancing Form 4 students' achievement in identifying prime numbers.

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