

The Design and Implementation of a Mathematics Game-Base Learning Application for Primary Students

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Abstract—The traditional learning process used in schools is outdated. Students nowadays spend most of their time using technologies for entertainment and to communicate with their friends. Technology can also be used to present opportunities in teaching difficult subjects, such as mathematics, in a better environment. This project aims to improve the mathematical skills of addition and subtraction in young children aged 6 to 8 by combining education and entertainment in a simple math learning game. Using ideas from Jerome Bruner's theory, and Bloom's Taxonomy of cognitive goals, this application will help children learn and interact effectively with the world around them. This project presents the design and development of a game-based learning application that improves the mathematical skills of young children. Specifically, our target-users for this application are primary school students who are learning addition and subtraction. This paper provides discussion and guidance on how to evaluate the impact of Mathematics Game-Base Learning Application. The overall results of the experimental study indicate a positive effect of Mathematics Game-Base Learning Application on the learning process.

Keywords—Learning, Education, Mathematics, Game, Children's Education.

1 Introduction

Learning-games help a student to improve his or her critical thinking skills, and acquire a more advanced level of education. Therefore, a higher quality of education results in a more satisfactory personal and academic achievement. Recently, electronic games have had a significant impact on children's lives. Hence, learning-games must combine more features to cater for more effective learning through technology (Gros, 2007).

Learning-games could be the best way to enhance education through rewards and challenges. Some researchers believe that knowledge acquisition for children through learning-games result in higher performance than knowledge acquisition during conventional teaching methods. The application should have a lot of features that shape a child's intelligence, which can affect the attitudes and behaviour (Yien, et.al. , 2011,

Lin et.al., 2017). Young children these day use smartphones and tablets to play, they can swap and tab before they can even walk or talk (Maltais, 2015).

We can channel these tablets and smartphones to be useful for all the children, especially for primary school students by engaging technology with education, and this is called Educational technology, which means: “The study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources” (Januszewski and Molenda, 2008).

Educational technology facilitates children in developing their hand-eye coordination, in developing their language skills, and in helping them gain appropriate skills before they go to the school. It also causes them to pay more attention to detail in order to solve an activity (McLeod , 2008).

This project incorporates educational techniques to produce an educational game in order to strengthen primary aged students’ mathematical skills in a fun and exciting digital environment, to stimulate their love of learning mathematics. The application includes several levels of difficulty to cater for any level student may be at, to help improve their education at school.

The main purpose of creating this application is to improve the mathematical ability in addition and subtraction of primary students from 6 to 8 years, by introducing a new concept of learning through the combination of education and entertainment in a simple game that provides what they need. This application is based on two theories about the learning skills which are: Jerome Bruner’s theory and Bloom’s Taxonomy of cognitive goals. This paper provides discussion and guidance on how to evaluate the impact of Mathematics Game-Base Learning.

2 Theories of Cognitive Development and Learning

2.1 Jerome Bruner’s Theory

According to Jerome Bruner, the important outcomes of a learning includes not only the concepts, categories, and problem-solving procedures invented previously by the culture, but also the ability to invent these things for someone (Takaya, 2008). He established three modes of representation, as illustrated in Figure 1.

2.2 Bloom’s Taxonomy of Cognitive Goals

Bloom and his colleagues established the most widespread classification in formulating and identifying objectives (Bloom, 1956). This classification divides the objectives into three areas:

- Cognitive domain
- Affective domain
- Psychomotor domain

Bloom was interested in dividing the cognitive domain, and gave most of his attention to other spheres, which this report will focus on. It concentrates on capacity or mental processes that relate to knowledge of facts, the operations of understanding and remembering, and discovering methods of identifying information and building concepts, principles, and generalizations (Clark et. al., 2004). Benjamin Bloom divided this area into six graded levels, from simple to complex, as shown in Figure 2.

‘Remembering’ is the simplest of these levels, followed by ‘Understanding’, and at the top of the pyramid is ‘Creating’, which is the most complex of these levels. The application focuses on the first three levels of the pyramid which are ‘Remembering’, ‘Understanding’, and ‘Applying’.

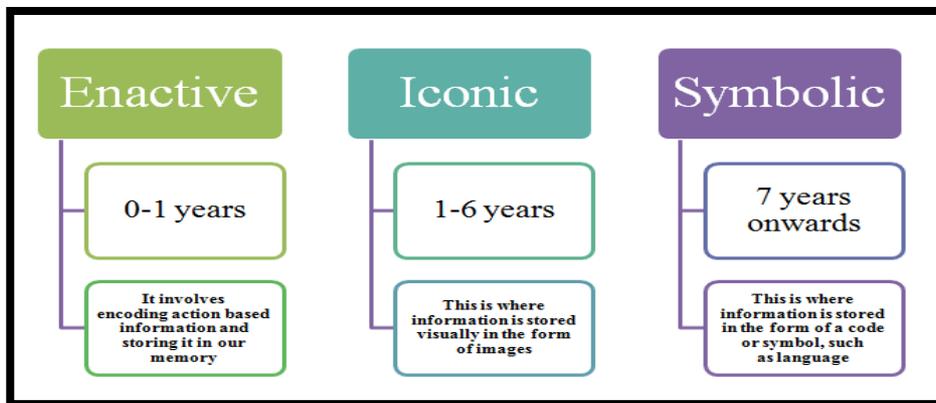


Fig. 1. Jerome Bruner's mode of representation

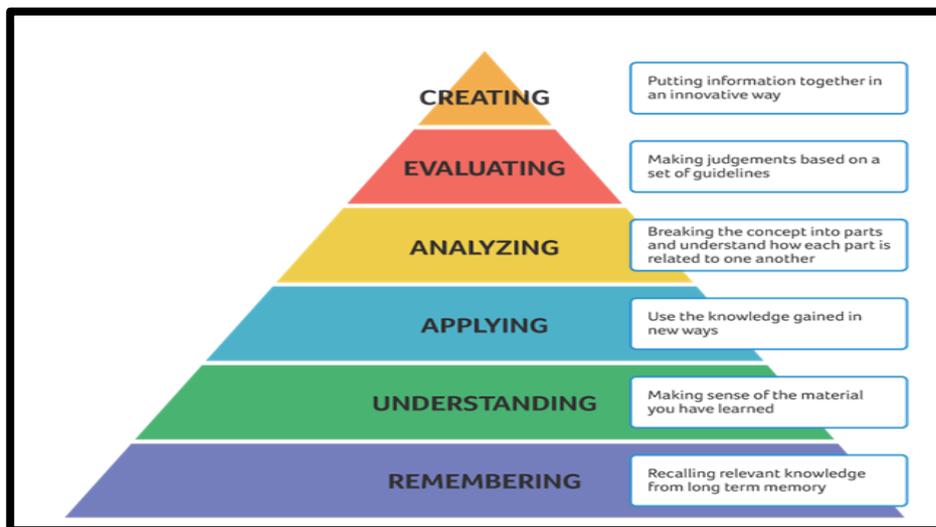


Fig. 2. Bloom's Taxonomy of Cognitive Goals.

3 Literature Review

This section explores previous applications for mathematics learning, thereby providing a clear understanding of the technology used in past works. There are many existing studies, several of which are discussed in this section.

3.1 IXL Learning (Longnecker, 2013)

- **Aims:** The aim is to help educators to identify specific tools that would help raise student self-efficacy and achievement through offering a fun, dynamic learning experience that meets the needs of their students.
- **Description:** The game consists of several levels and each level of the game has many skills they build on:
 - Pre-K math has 77 skills.
 - Kindergarten math has 182 skills.
 - First grade math has 205 skills.
 - Second grade math has 275 skills.
 - Third grade math has 370 skills.
 - Fourth grade math has 322 skills.
 - Fifth grade math has 335 skills.
 - Sixth grade math has 320 skills.
 - Seventh grade math has 289 skills.
 - Eighth grade math has 317 skills.
 - Ninth grade (Algebra 1) math has 305 skills.
 - Tenth grade (Geometry) math has 217 skills.
 - Eleventh grade (Algebra 2) math has 311 skills.
 - Twelfth grade (Pre-calculus) math has 261 skills.

3.2 Gem-Game (Giannakos, 2013)

- **Aims:** The main aim of Gem-Game is to improve the mathematical skills of players.
- **Description:** This game starts with introducing the main character (Peter) who then moves up or down depending on the operation executed by the player. Thus, students get a visual idea of increasing quantity when adding, and decreasing quantity when subtracting, with each storytelling game consisting of some common stages. In the first stage (Figure 2.3), the hero is situated in the ordinary world; in our game, the hero named Peter is in his bedroom and looking for his dog. Then the hero is presented with a problem or event that necessitates leaving the comfort of the ordinary world because Peter's dog, Lucky has been kidnapped. Next, the hero meets a mentor or someone who may offer advice or guidance; the fairy guides Peter to collect 30 diamonds. Once the hero commits to the adventure, he begins the problem-solving process. During this process, the hero encounters various challenges that he must overcome in order to progress. In this stage, Peter has

to play and win the game in order to collect the necessary diamonds. The ultimate goal of the player is to retrieve his dog by collecting diamonds. To achieve the ultimate goal, Peter must win the three stages. Specifically, Peter must correctly add/subtract in order to earn diamonds.

3.3 Kahoot math game (Kahoot!, 2017)

- **Aims:** The game aims to unlock and improve educational skills; It can be played alone or with others. It provides learning in multiplication of functions, addition and subtraction of functions, division with whole numbers and unit fractions, percent problems, ratios proportions, and mean with fractions.
- **Description:** In this game, the teacher can make fun motivational challenges as homework for students. This game can also be used by sending the PIN to friends to promote teamwork and healthy competition. The students play fun learning game as an alternative to learning on paper as a change of routine. There is also an option to play together as a class. The questions will show on a shared screen and the winner is the one who answers the first.

3.4 Math Playground games (Math playground, 2017)

- **Aims:** It introduces all concepts of math and is a safe website for children. Some of the activities for problem solving that support educational skills are math games, logic puzzles, math arcade, story math, math video lessons, and CCSS.
- **Description:** A more popular mathematics-based learning-game site where parents facilitate their children's learning, Math Playground games provide interactive exercises and are for online use only. Children can play and learn, having fun simultaneously.

3.5 Axiom game (Axiom, 2013)

- **Aims:** It helps a child to improve thinking skills in a fun way. The game provides a challenging and engaging educational experience, not only for children but also for adults
- **Description:** It is a free mathematical-based game found on the App Store. The player controls movement of the ship to solve the math equations and by avoiding a series of deadly traps. The game is suitable for all ages above four years old. It has more than 80 levels (from easier to harder) using animated graphics with rhythmic soundtracks, sounds and beautiful colours. The timer calculates the time that would challenge the players to being the quickest mind and smartest mathematician.

3.6 Marble Math (artgigapp, 2015)

- **Aims:** The aim of the game is to solve a variety of math problems by collecting numbers and bonuses as you navigate a series of mazes with your marble.
- **Description:** Marble Math is a fun and educational activity for children learning addition. There are three different levels of addition and a fun bonus activity after each level. Children must score 80% or greater to advance to the next level. It has an audio feature that helps children understand how to count and play the activity.

4 Design and Implementation of the Application

The Mathematics Game-Based Learning Application was designed and developed to improve the mathematical ability in the area of addition and subtraction for children aged 6 to 8 years old, introducing a new concept of learning through combining education and entertainment in a simple game in effort to enable them to learn and interact effectively with the world around them. The application is based upon Jerome Bruner's theory, and Bloom's Taxonomy of cognitive goals.

User interface is the space where interactions between the users and machines occur. User interface design is important especially to our target users who are children from 6 to 8 years old. It must be simple, easy to understand and to navigate, and self-explanatory to the user. It also includes images and drawings based on Jerome Bruner's theory and audio stimuli in the Arabic language. This application used Android Studio and Java Programs for implementation, also this application used a Java code that create a random mathematical operation and store it in the program itself. A game application, there is no need for a large database.

The application is comprised of three levels:

- Level 1 (easy): This level will show maze and questions for order of numbers.
- Level 2 (medium): This level will show maze and questions for addition and subtraction of numbers.
- Level 3 (hard): This level will show maze and questions for addition and subtraction with images.

It also contains an "About Mathy" page that outlines the instructions for the game.

4.1 Main Screen

The first main screen contains a place for the logo, start button and "About Mathy" button; the second main screen contains three sections (see figure 3):

- Level 1 (Order Numbers)
- Level 2 (Add and Subtract Numbers)
- Level 3 (Add and Subtract with Shapes)



Fig. 3. Main Screen

4.2 Level 1 (Order Numbers) Section:

If the user chooses the Level 1 (Order Numbers) section, the application will display another screen that contain the maze and questions for order number, see Figure 4.



Fig. 4. Level 1 (Order Numbers)

4.3 Level 2 (Add and Subtract numbers) Section:

If the user chooses the Level 2 (Add and Subtract numbers) section, the application will display another screen that contains the maze and questions for the addition and subtraction of numbers (see Figure 5).

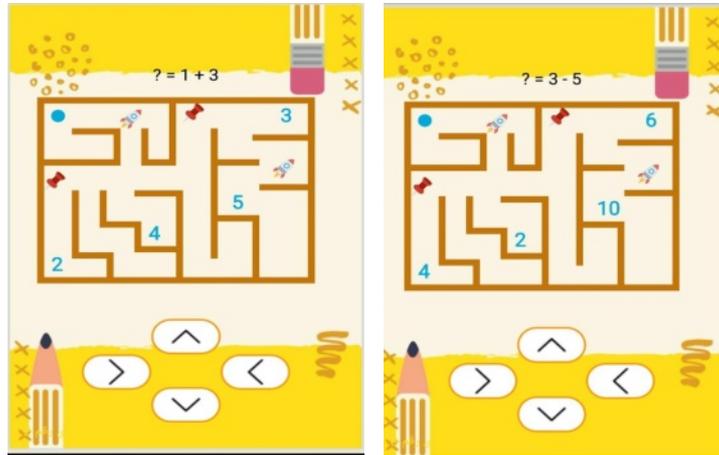


Fig. 5. Level 2 (Add and Subtract Numbers) Section

4.4 Level 3 (Add and subtract with Images) Section:

If the user chooses the Level 3 (Add and Subtract with Shapes), the application will display another screen that contains the maze and questions for addition and subtraction with shapes (see Figure 6).

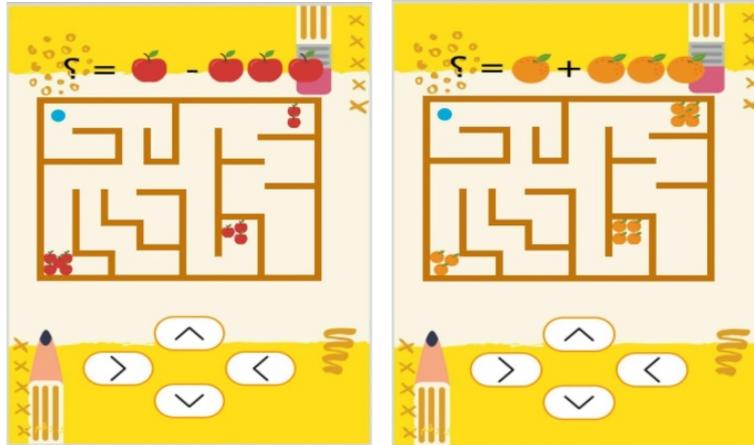


Fig. 6. Level 3 (Add and Subtract with images) Section

5 Method

5.1 Participants and Study Design

The purpose of this project is to create an application for primary students from 6 to 8 years old that will help them improve their mathematical ability in addition and subtraction and sorting the numbers.

50 primary students from different schools in Jeddah participated in the testing process divided into: 25 male students and 25 female students to test the running application.

We visit Riyadh Alretaj National School (for female) and Alriyadh School (for male) to make the students take a pre-test and post-test and record their scores. The test starts in December 2017 and February 2018.

5.2 Paired t-test

Pre-Test Exam: we made a paper that supports the traditional way of learning that contain multiple questions with addition, subtraction and order equation and make the participants take the exam to record their scores.

Post-Test Exam: we let the participants use our application to record their scores and compare it with the scores that come from the traditional way of learning.

Hypotheses: The hypotheses can be expressed in two different ways that express the same idea and are mathematically equivalent:

The “Null Hypothesis” might be:

H0: There is no difference in mean pre-test and post-test.

And an “Alternative Hypothesis” might be:

H1: There is a difference in mean pre-test and post-test.

6 Results

6.1 Descriptive Statistics

As shown in table1 , The mean of pre testing for both groups (male and female) was 5.92 (SD = 1.226) , also The mean of post testing for both groups (male and female) was 6.82 (SD = .438)

Table 1. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Gender	50	1	2	1.50	.505
Pre_Testing	50	3	7	5.92	1.226
Post_Testing	50	5	7	6.82	.438
Valid N (listwise)	50				

6.2 Paired t-test

From this row observe the t statistic, $t = -5.382$, and $p = 0.000$; a very small probability of this result occurring by chance, under the Null Hypothesis of no difference. The Null Hypothesis is rejected, since $p < 0.05$ (in fact $p = 0.000$). See table 2

Table 2. Paired T-Test Statistics

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre_Testing - Post_Testing	-.900	1.182	.167	-1.236	-.564	-5.382	49	.000

7 Conclusion & Discussion

This Mathematics Game-Based Learning Application it is an application aimed at helping primary-aged students to learn and improve their mathematical ability in addition and subtraction. In this Game-Based Learning Application, the theories that have been employed to study and determine children’s learning skills are *Jerome Bruner’s Theory and Bloom’s Taxonomy of Cognitive Goals*. To this end, the Mathematics Game-Based Learning Application has been created with the intention to benefit the children by developing and improving their abilities and skills, and to ease their learning experience. We examine the purpose of the test, functions correct paths for each the tasks, goal of testing, participants, the actual performance of the tasks, methods used in the test process, processing testing, analyzing the result. We analyze the Paired T-Test and there is strong evidence ($t = -5.382$, $p = 0.000$) that the teaching intervention improves scores by using game-based learning application. In this data set, it improved scores. This is why it is important to look at the 95% Confidence Interval (95% CI).

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9 References

- [1] Axiom, Diwaniya, 2013. Available from: <<https://itunes.apple.com/US/app/id599400946?mt=8&ign-mpt=uo=4>>. [Jun 02 2013].
- [2] Bloom, B.S. (Ed.). Engelhart, M.D., Furst, E.J., Hill, W.H., Krathwohl, D.R. (1956). *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain*. New York: David McKay Co Inc.

- [3] Clark, R., Chopeta, L. (2004). *Graphics for Learning: Proven Guidelines for Planning, Designing, and Evaluating Visuals in Training Materials*. San Francisco: Jossey-Bass/Pfeiffer.
- [4] Giannakos, M.N., 2013. Enjoy and learn with educational games: Examining factors affecting learning performance. *Computers & Education*, 68, pp.429-439. <https://doi.org/10.1016/j.compedu.2013.06.005>
- [5] Gros, B., 2007. Digital games in education: The design of games-based learning environments. *Journal of research on technology in education*, 40(1), pp.23-38. <https://doi.org/10.1080/15391523.2007.10782494>
- [6] Januszewski, A., & Molenda, M. (2008). *Definition: Definition and Terminology Committee of the Association for Educational Communications and Technology. Educational Technology: A Definition with Commentary* (2nd ed., pp. 1-4). New York, NY: Lawrence Erlbaum Associates.
- [7] kahoot! 2017. available from: <https://kahoot.com/explore/collections/math-kahoot-fractions>. [28 October 2017].
- [8] Lin, M. H., Chen, H. C., & Liu, K. S. (2017). A Study of the Effects of Digital Learning on Learning Motivation and Learning Outcome. *Eurasia Journal of Mathematics, Science and Technology Education*, 13(7), 3553-3564 <https://doi.org/10.12973/eurasia.2017.00744a>
- [9] Longnecker, R.W., 2013. IXL. com—measuring the effects of Internet-based math instruction on the math achievement of middle school students. Trevecca Nazarene University.
- [10] Maltais, M. (2015). Even young children are tech savvy, some using mobile devices before age. *Los Angeles Times*. [Online] Available at: <http://www.latimes.com/science/science-now/la-sci-sn-young-children-tablets-pediatrics-20151102-story.html>
- [11] Math playground 2017. Available from: <https://www.mathplayground.com>. [28 October 2017].
- [12] McLeod, S. A. (2008). Bruner. Retrieved from www.simplypsychology.org/bruner.html
- [13] Takaya, K. (2008). Jerome Bruner's theory of education: From early Bruner to later Bruner. *Interchange*, 39(1), 1-19. <https://doi.org/10.1007/s10780-008-9039-2>
- [14] Yien, J. M., Hung, C. M., Hwang, G. J., & Lin, Y. C. (2011). A game-based learning approach to improving students' learning achievements in a nutrition course. *Turkish Online Journal of Educational Technology*, 10(2), 1-10.

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