IMPACT OF DIGITAL GAME-BASED LEARNING ON MATHEMATICAL LEARNING OF ELEMENTARY SCHOOL STUDENTS: A MINI REVIEW

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ABSTRACT: *Video games are known to be a common preferred type of entertainment among children and adolescents. Therefore, an increasing number of researchers and educators benefited from the wide popularity of video games and started to incorporate educational video games in formal and informal classroom settings in an attempt to improve the learning experience of students. This study aims to provide a critical review that investigate and evaluate the impact of educational video games on the mathematical achievements of elementary-aged students. Game-based learning improves the mathematical learning outcomes of students. A brief review of research articles that have focused on the role of DGBL in the education of elementary school students in the area of mathematics.*

Keywords: elementary education; digital game-based learning; mathematical learning, and computer games

1. INTRODUCTION

Videogames are enjoyed by the vast majority of people, particularly children and adolescents. It is estimated that children and adolescents in the United States spend around seven hours per week playing videogames. Hence videogames have captured substantial research attention [1,2].

Computer videogames are capable of improving the emotional and psychological states of the player, reduce stress and provide a sense of satisfaction [3,4]. In addition to the emotional and psychological well being of the player, video game players have stated that videogames assist them to interact and socialise with family and friends [5-7]. Videogames attract players and motivates them to play. However, games with no clear motivation will be unsuccessful in capturing the attention of players and such games will sound aimless [8].

Extensive videogame playing has a number of consequences on the physical well being of the player such as obesity [9], serious thumb pain [10]. The negative impact of extended video game play is not exclusively detrimental to the physical well being of the player but can also affect the behaviour of the player. The American Psychological Association (APA) has called for a decrease in the violent content of videogames due the fact that these games play a key role in increasing aggressive behaviour, aggressive thoughts and angry feelings [11].

Videogames are employed in the educational field to promote as well as to enhance the academic performance of students and to motivate them [12,13]. The implementation of videogames assists students to enhance their learning attitudes and cognitive gains [14]. Educational videogames also achieve a higher level of retention amongst students compared to traditional teaching approaches [15].

This study will examine the existing and recent research literature that investigated the impact of educational videogames on elementary school students in order to reveal its effects on their academic performance in mathematics, motivation and attitude. It is hoped that this study will be useful for future researchers, educators and educational game designers in the area of mathematics and other teaching areas. The research questions of this study are as follows:

1. What is the effect of DGBL on students' mathematics learning?
2. What is the effect of DGBL on students' learning experience?
3. What is the effect of DGBL on students' genders?
4. What are the current research gaps?

2. METHODOLOGY

2.1 Data collection

The online repositories searched in this review include the Institute of Electrical and Electronics Engineers (IEEE), the Association for Computing Machinery (ACM), Web of Science [v.5.18], ScienceDirect, Education Research Complete (ERC) and the Education Resources Information Centre (ERIC). ERIC is considered to be the largest educational research database and contains an enormous number of publications related to this field [16].

2.2 Keywords

The keywords used in this review are "game based learning", and "educational game". In order to refine the search entries thus obtained, especially from ERC and Web of Science, another set of search strings were applied as NOT "secondary education", NOT "college" and NOT "undergraduate".

2.3 Selection Criteria

A number of rules were specified to assure that only the appropriate papers would be included in this review. For a paper to be included, it had to be published from 2008 to 2016, written in English and be a journal in the area of mathematics, include an experiment with an educational videogame and lastly include participants which must be elementary school aged students. This means that proceedings, books and research reports were all excluded from the review, as were studies that included participants from elementary schools, middle schools and high schools. Furthermore, if a study incorporates another subject besides mathematics that study will also will not be included in this review.

2.4 Categorization of papers

When the aforementioned parameters were applied. The articles included in this review are categorized mainly into three, arithmetic operations, mental computational skills and miscellaneous mathematical concepts.

3. RESULTS

This section will provide a brief and partial demonstration for the research articles that falls into the Mental Computational Skills category.

3.1 Mental Computational Skills

Students' mental computational skills in arithmetic operations were tested and evaluated via a wide number of learning strategies and technologies. In [17] an application called Motion Math: Hungry Fish was employed to provide students with the help they need to understand the mathematical concepts of addition and subtraction. In the proposed application a hungry, colourful and labelled fish appears on the screen. The label on the fish is a number which the player is required to reach through addition and subtraction. The player reaches the targeted number by feeding bubbles to the fish. Motion Math: Hungry Fish also provide the player with more than one way to reach the targeted number. Correct answers will make the fish grow bigger in size and allow the player to open new levels, while incorrect answers will make the fish shrink smaller in size. Motion Math: Hungry Fish consists of several levels and changing levels will improve the user's perception of the game flow experience.

The issue of the students' confidence with regard to mathematics was explored in [18]. The study designed two mini-games in the area of mental mathematical calculations. The first game is a strategy-based board game called Battleship in which the player is given a question and a correct answer within a determined time frame will give the student the opportunity to attack the opponent's ship. An incorrect answer and the player will lose the privilege of attacking. The second game is a soccer/football game called Math kicker. In this game, the player shoots the ball to score a goal. When a goal is scored the students' points will increase.

In [19] a study was carried out to compare that compared the employment of COTS Handheld Game Consoles (HGCs) and traditional teaching methods on the development of mental mathematical calculations and self-perception.

In [20] a modified 3D version of a commercial game called Monkey Tales was utilized to investigate its effects on the mental arithmetic skills of students. The proposed game motivates the students to perform drill exercises under an increasing time pressure.

The perception of students with regard to the use of HGC to improve their mathematics skills was addressed in [21]. The students were asked to play one of Dr Kawashima's Brain Training Games called X20. In this game, students are required to answer addition, multiplication and subtraction questions for a maximum period of 20 minutes on a Nintendo DS Lite device in an attempt to improve their mental mathematical skills.

Two versions of a computer game called The Number Race was employed by the authors of [22] to explore the impacts of the proposed game on mental representations of numbers. Students played two versions of The Number Race. The player in the approximate version is faced with dots displayed on the interface of the game and two suggestions, in which one of the suggestions differs from the displayed number by only one and the second differs by more than two. The player in the exact version is challenged with a number dots and two suggestions of dots, one of the choices resembles the number displayed on the screen and the second differs slightly. The third group of students used "Oriolus" which is a learning environment based on the German language.

4. RESULTS AND DISCUSSION

This paper provides a brief review of research articles that are related to the use of DGBL in elementary schools in the area of mathematics.

The results this study obtained thus far demonstrates that when videogames are used appropriately and under supervision, they benefit the students significantly. Students who are guided by DGBL achieve higher learning outcomes compared to students who are guided by traditional teaching and non-game-based methods.

This study found that DGBL is a dynamic learner-centred concept that can be used independently or incorporated with teaching techniques. DGBL operates on several platforms – computers, and other handheld devices. It provides learners with the opportunity to work individually or collaboratively. It is also capable of providing students with a wide range of educational videogames such as puzzles, strategy, memory and planning.

The early findings this study obtained thus far clearly indicate that the majority of research articles in the Mental Arithmetic Operations category faced a common limitation which is a small research sample. In other words, the results these studies acquired are difficult to generalize because the number of students participated in the aforementioned studies was limited. In addition to the previously mentioned challenge, another obstacle that stands in the face of greater DGBL deployment in elementary schools is the relatively high financial cost of electronic devices required to facilitate the use of educational videogames as educational tools. However, such obstacles can be overcome by collaborative learning in which a number of students share one device [13, 23,24], Other approaches utilised collaborative learning coupled with the "cheapest technological support" [25].

Educational videogames are non-conventional learning tools. When educational institutes invest in or rely on educational videogames they will not only gain students with high

Table 1: Information of participants, major findings and limitations of DGBL in mathematics.

Name	Research sample	Finding(s)
Hung et al. (2015)	Participants: 52 second grade students (mean age= eight years old), (M= 24, F= 28). Groups: experimental group played levels (seven–14) challenging games (N= 22), control group played levels	1. The post-test scores of the students indicated that the learning outcomes of the experimental group were significantly higher than the scores of the control group. 2. Students in the experimental group showed higher flow experience than students in the control group. 3. The four dimensions of flow experience showed a statistical significant difference in flow experience and flow antecedent. However, there were no statistical significant

	(one–six) matching games (N= 21).	differences in intrinsic motivation and extrinsic motivation. 4. Students in the experimental game achieved significantly better perception of the benefits offered by Motion Mathematics: Hungry Fish, and were superior to their counterparts in the control group at moderating the self-efficacy for science and self-efficacy for technology on flow experience.
Ku et al. (2014)	Participants: 51 fourth grade students (10–11 years old). Groups: Experimental Group (EG) used DGBL environment (N=26, M= 12, F= 14). Control Group (CG) used traditional learning approaches (N= 25, M= 10, F= 15).	1. The confidence of EG students increased in the post-test. However, there was no significant increase among the CG students. 2. DGBL may help students to produce more accurate answers. 3. High and low achievers benefitted from the DGBL experience. 4. The computational performance of high achievers in the control group improved substantially in the post-test.
Main and O'Rourke (2011)	Participants: 59 fourth and fifth grades students. Experimental group: used the Nintendo DS HGC with Dr Kawashima's Brain Training game. Control group: was taught using the traditional teaching methods.	1. The mathematical scores of the experimental group were significant and the control group scores were not significant. 2. Students in the experimental groups demonstrated an enhanced self-concept towards mathematics. 3. Both boys and girls showed similar significance in their pre and post mathematical tests. 4. The girls showed higher levels of significance compared to boys in their post-trial self-perception.
Núñez et al. (2015)	Participants: 67 third grade students (eight years old), (M= 45, F= 22). Groups: experimental group was taught using Monkey Tales (N= 25, M= 17, F= eight), the control group was taught using the paper exercises (N= 25, M= 17, F= eight).	1. The accuracy of the students in the experimental group was higher than the accuracy of the students in the control group. 2. With respect to the speed of completion of the mathematics test the post-test scores showed that students in both groups were significantly faster. 3. Students in the experimental group stated that learning with the educational game was an exciting experience. Whereas, students in the control group stated the opposite. 4. The percentage of students who expressed their willingness to repeat the experience again was higher in the experimental group (93 %) to (76 %) in the control group.
O'Rourke et al. (2013)	Participants: 258 fourth and fifth grades students (nine–11 years old), (M= 128, F= 130).	1. The hand-held consoles (HGC) assisted the students to improve their mental mathematical scores. 2. Students associated the process of learning using HGC with a lot of positive feelings and were engaged, motivated and focused.
Obersteiner et al. (2013)	Participants: 147 first grade students (mean age = 6.9 years old). Groups: group A (Approximate, played the approximate version of the game), group E (Exact, played the exact version of the game), group AE (Approximate+Exact, used both versions Approximate and Exact), group CG (Control Group played Orioulus).	1. No significant difference in the maximum game level reached by the students in (A, E, AE). 2. There was also no significant difference in the number of tasks. 3. The difference in accuracy between groups A and E was significant with higher accuracy for group A. No significant difference in accuracy between group A and AE. 4. Students in group A were faster than students of group E in solving tasks. 5. The whole sample experienced a reduction in reaction time in posttest evaluations. 6. The subitising abilities of students in the experimental groups were superior to students in the CG. 7. There was an overall arithmetical achievement for the whole research population.

learning achievement rates, but they will also play a noble role in reducing the number of trees being cut to make paper-based books. Furthermore, the CO_2 emissions and energy consumptions caused by computer-based education are less than the CO_2 emissions and energy consumptions caused by traditional instructional methods [26].

5. CONCLUSION

In conclusion, this paper provided a brief review of research articles that have focused on the role of DGBL in the education of elementary school students in the area of mathematics. Students who were guided by educational videogames benefitted academically in the form of increased learning achievements and knowledge acquisition. The findings of this study are limited to the keywords used, the databases searched and the time period.

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