

The Impact of Video Games in Children's Learning of Mathematics

Muhammad Ridhuan Tony Lim Abdullah, Zulqarnain Abu Bakar, Razol Mahari Ali,
Ibrahima Faye, Hilmi Hasan

Abstract—This paper describes a research project on Year 3 primary school students in Malaysia in their use of computer-based video game to enhance learning of multiplication facts (tables) in the Mathematics subject. This study attempts to investigate whether video games could actually contribute to positive effect on children's learning or otherwise. In conducting this study, the researchers assume a neutral stand in the investigation as an unbiased outcome of the study would render reliable response to the impact of video games in education which would contribute to the literature of technology-based education as well as impact to the pedagogical aspect of formal education. In order to conduct the study, a subject (Mathematics) with a specific topic area in the subject (multiplication facts) is chosen. The study adopts a causal-comparative research to investigate the impact of the inclusion of a computer-based video game designed to teach multiplication facts to primary level students. Sample size is 100 students divided into two i.e., A: conventional group and B conventional group aided by video games. The conventional group (A) would be taught multiplication facts (time-tables) and skills conventionally. The other group (B) underwent the same lessons but with supplementary activity: a computer-based video game on multiplication which is called Timez-Attack. Analysis of marks accrued from pre-test will be compared to post- test using comparisons of means, *t* tests, and ANOVA tests to investigate the impact of computer games as an added learning activity. The findings revealed that video games as a supplementary activity to classroom learning brings significant and positive effect on students' retention and mastery of multiplication tables as compared to students who rely only upon formal classroom instructions.

Keywords—Technology for education, Gaming for education, Computer-based video games, Cognitive learning

I. INTRODUCTION

BASED on the curriculum specification of Year 3 Mathematics issued by the Ministry of Education of Malaysia [13], one of the main objectives requires children to master the basic operation of Mathematics: addition, subtraction, multiplication, and division. Under multiplication, students are expected not only to 'know by heart' the multiplication tables but also be able to recall the multiplication facts rapidly (p.14).

Muhammad Ridhuan Tony Lim Abdullah was with University of Malaya. He is now with the Management & Humanities Department, Petronas Universiti of Technology, Tronoh, 31750 Perak, Malaysia (phone: +6053687769; fax: 6053656280; e-mail: ridhuan_tony@petronas.com.my)

Zulqarnain Abu Bakar is now with the Management & Humanities Department, Petronas Universiti of Technology, Tronoh, 31750 Perak, Malaysia (e-mail: zulqab@petronas.com.my)

Razol Mahari Ali is now with the Management & Humanities Department, Petronas Universiti of Technology, Tronoh, 31750 Perak, Malaysia (e-mail: razolma@petronas.com.my)

Ibrahima Faye is now with the Fundamental and Applied Science Department, Petronas Universiti of Technology, Tronoh, 31750 Perak, Malaysia (e-mail: ibrahima_faye@petronas.com.my)

Mohd Hilmi Hasan is now with the Fundamental and Applied Science Department, Petronas Universiti of Technology, Tronoh, 31750 Perak, Malaysia (e-mail: mhilmi_hasan@petronas.com.my)

Learning multiplication and memorizing the times tables nevertheless seemed to be the foundation of higher level topics in mathematics learning such as long multiplication, division, fractions, geometry, algebra; and calculus. Students who failed to master the multiplication tables would face extra difficulties in coping with the learning of these levels compared to their other students who memorized the tables, which may lead to lack of leaning confidence among them as they systematically fall behind in maths and other maths related subjects. The general teaching approach by schools would be subjecting the children to long-standing tradition of memorizing multiplication facts through drills and lengthy practices, take-home worksheets, flashcards, and other memorization aids. Periodical formative timed tests were used as a standard tool to monitor the children's ability to recall multiplication facts; though it was uncertain whether these tests could encourage the children to memorize. However, the boring task of memorization over the years is compensated through fun-filled exciting activities with the aid of music, games and role-playings purportedly to reinforce retention of math facts.

Under the recent influence of ICT, computer-assisted instruction (CAI) programs could significantly motivate, enhance curiosity and control through exciting challenges, and promote children's imagination skills [19]. However, the presence and popularity of digital media such as computer-based video games have gathered significant pace in their use in education and researchers as well as game developers are investigating how these digital games could impact on children's cognitive learning [3] [18] [20]. For example, Pillay [14] conducted a study on how recreational computer games could influence children's subsequent performance in instructional tasks. Studies in video games in Mathematics education revealed that video games help people improve their basic math abilities [10]; promotes innovative mathematical thinking skills and is suggested to be an ideal medium to teach middle-school math as part of the teaching kit [7]; and are suggested to be typically used in factual recall [12].

While some educators assume great interest in the effects of video games in enhancing players' learning skills [1] [17], others take a more cautionary stand by viewing video games as promoting violence, social isolation, aggression, or negative imagery of women [2] [15]. Video games in this light have been regarded as pure entertainment. This is owing to the nature of video games being designed for mere profit gain by business organizations and video game designers. In 2008, a whopping \$21.33 billion was accrued through computer and console game software and hardware in the United States alone, and a staggering \$54 billion gained worldwide through this gaming industry (Wikia 2008). Education has given less to no priorities in the design of video games to date. Video games till present are mostly designed for action games although video games could also include other genres such as adventure, strategy, simulations, role-playing, puzzles, or sports. The invaluable asset of good design of these games is in the way the players are immersed in rich interactive digital

world. Through this immersion, video games make it possible for users to have an almost authentic feel of piloting a jet fighter (Jetfighter IV) or sent back to the past to engage in planning and plotting a war strategy (Call of Duty, Commandos, Modern Warfare); raising a family (The Sims); saving humankind in imaginary post apocalypse era (Resident Evil), or engage in role-playing task (Final Fantasy). Although we are witnessing a rising numbers in educational game softwares especially in the simulation genre, there is still a large gap in research on how these games are used and implicate learning. However, in favour of video games, studies have been conducted to investigate ways to incorporate motivational aspects of video games into instructional design [5] [6] [8].

Past literature also indicated that game and play are some of the best approaches for learning [9] [11]. However, contemporary society and educational discourse regards human learning only to be achieved through non-playful process as the public has associate gaining knowledge with hard labour. In contrast to this dominant belief that learning is through great effort and persistence, play and enjoyment can and should be considered as an integral part of a learning process. Although extensive studies have been done on educational computer games in Malaysia, this country is still behind other countries and most of the studies and researches carried out here focus more on students' and teachers' perception and attitude towards accepting computer games in education and computer games as motivational tool for learning [16]. A wide gap still exists in studies focusing on the effectiveness of computer or video games in children's learning of certain subjects in schools. Hence, this research aims to investigate the effectiveness of computer-based video game in facilitating children's learning of multiplication facts in Mathematics. In the interest of achieving this aim, the study adapted a similar study conducted by Blunt to determine the effectiveness of computer-based video games in children's learning of multiplication facts in Mathematics [4]. In his study, Blunt seeks to investigate the relationship between the use of video games and learning among students at tertiary level. However in this research, the study aimed to seek whether video games could affect children's learning.

In order to achieve the above objective, this study attempts to answer the research questions below:

1. What was the difference in learning achievement of multiplication facts between children who are aided by computer-based video game in learning and those who were not?
2. What was the difference in learning achievement of multiplication facts between boys and girls who were aided by computer-based video game in learning?
3. What was the difference in learning achievement of multiplication facts between urban and rural children who were aided by computer-based video game in learning?
4. What was the difference in learning achievement of multiplication facts among below average, average and above average levels of children who were aided by computer-based video game in learning?

II. METHOD

The study adopted a causal-comparative research to investigate the effectiveness of computer game as an additional activity in the learning of multiplication facts among primary level students. Since the review of literature indicates a strong opposition towards the inclusion of video games in education, the researchers are committed to a neutral stand to find out whether computer-based video games are destructive in children's learning process or enhance the children's learning. Although there are evidences of negative effects of video games to children, one cannot totally ignore the potential of video games as future tools of delivering educational and training material. This is because computer and video games have become relevant as cultural medium as books, television and films especially for children and teenagers of today. The video game used in this study, Timez-Attack, is a free downloadable game produced by Big Brainz Inc., California. Timez-Attack is a commercial game which is specifically designed to teach multiplication facts to children. This game, available at <http://www.bigbrainz.com/index.php>, was proposed as a supplementary classroom activity in schools or educational activity at home. Causal-comparative research was assumed by this study as it enables the researcher to investigate the effect of computer-based video game on children's learning by comparing differences in groups or individuals. This method further enables the researcher to determine the reasons or causes underlying the effects and differences among the groups of participants [21].

The study aimed to produce sets of data to compare the learning achievement between students who participated in the game and students who did not. Data sets included gender, race, and locality (urban students versus rural students). The various data groups were assessed through similar tools (or materials) and situations of testing and to facilitate a comparison quantitatively between students who were aided by computer-games and students who were not. Both groups of students had the same learning material and knowledge input apart from the video game to reinforce the credibility of findings generated from students' participation in the video game. In the expectation of the data approximately normally distributed, normal curve goodness of fit testing was used to test the assumptions. These tests were based on different sample data pairs as indicated in the research questions and the accompanying hypothesis.

A. Design of Study

Approximately 100 primary level school children of two randomly selected schools in Perak (from one urban area school and one rural area school) will participate in the study. All students will be given a pretest on multiplication facts. Marks accrued from the test individually will be used to divide the students into two groups which should be equal in numbers and in students' performance. This is partly to ensure validity and reliability of the results of the experiment. The marks will also be compared with post test results later; analysis of results using comparisons of means, *t* tests, ANOVA, and chi-squared tests will be used to investigate the efficiency of computer games as an added learning activity.

The control group will be taught multiplication facts and skills conventionally. The experimental group would also undergo the same lessons but with the added activity: a computer-based video game on multiplication which is called Timez-Attack. The equal distribution of students of high and low achievers for both control and experimental groups are carefully administered. The study was conducted for three months. All participants were given a timed post-test to gauge students' accurate recall of multiplication facts in a given time accurately. Knowledge improvement from pre to post facilitated the outcome measures for the study.

III. FINDINGS

Based on the analysis of pre and post test, triangulated with interview data and observations, the study was targeted to inform on the impact of video games on students' learning of multiplication facts in terms of retention measured through instantaneous recalling of the facts (multiplication timetables from 2 to 12) with accuracy and concept of multiplication (application of facts on multiplication problems). Results accrued from the study fall under any of these three categories : 1) results revealed a significant improvement on students' learning of multiplication fact using video games compared to conventional learning; 2) results revealed a non-significant improvement on students' learning of multiplication fact using video games compared to conventional learning or no difference in improvement of learning; 3) results revealed a significant decrease in students' learning of multiplication fact using video games compared to conventional learning. Thus the outcome revealed whether video game is relevant, or not relevant to its incorporation in formal classroom learning.

A. Research question 1

What is the difference in learning achievement of multiplication facts between children who were aided by computer-based video game in learning used computer-based video game in learning and those who were not? Table I shows the hypothesis and null hypothesis corresponding to Research question 1.

TABLE I

HYPOTHESIS (RESEARCH QUESTION 1): OVERALL EFFECT OF INCLUSION OF VIDEO-GAME IN LEARNING

Hypothesis 1	Statement of Hypothesis
Null Hypothesis 1	H_0 $\mu_1 \geq \mu_2$
	The average test score for children who were not aided by Timez-Attack is greater than or equal to the average score for children who were aided by Timez-Attack, where μ_1 is the mean test score of children who were not aided by Timez-Attack and μ_2 is the mean test score of children who were aided by the game.
Alternate Hypothesis 1	H_1 $\mu_1 < \mu_2$
	The average test score for children who were aided by Timez-Attack is greater than the average test score for children who were not aided by Timez-Attack, where μ_1 is the mean test score of children who were not aided by Timez-Attack and μ_2 is the mean test score of children who were aided by the game.

Since the emphasis was on higher scores represented on one end of sampling distribution, a one-tail t test for equality of means was used in the analysis. The set of test scores from children who were not aided by the game was compared to the

set of test scores from children who were aided by the game in Table II.

TABLE II
ONE-TAIL T TEST

	All w/o Game	All w/ Game
Mean	27.925	14.375
Variance	101.5057	91.08737
Observations	50	50
Pearson Correlation	0.274421	
Hypothesized Mean Difference	0	
Df	49	
t Stat	8.102917	
P(T<=t) one-tail	6.65E-11	
t Critical one-tail	1.676551	
P(T<=t) two-tail	1.33E-10	
As $p < .05$, reject H_0		

1. Hypothesis:

$$H_0: \mu_1 > \mu_2$$

$$H_1: \mu_1 < \mu_2$$

2. $\alpha = .05$

3. Test statistic: t statistic for a one-tail t test equality of the means

4. Decision criterion: Reject H_0 and accept H_1 if p -value $< .05$

5. Calculation: p -value = 6.65E-11

6. Conclusion: Based on the results of this sample and analysis, there was a significant difference between the two means. The average test score for children who were aided by Timez-Attack is significantly greater than the average test score for children who were not aided by the game.

B. Research Question 2

What was the difference in learning achievement of multiplication facts between boys and girls who were aided by computer-based video game in learning? Table 3 presents the hypothesis and null hypothesis corresponding to Research Question 2.

TABLE III

HYPOTHESIS (RESEARCH QUESTION 2): EFFECT BY GENDER

Hypothesis 2	Statement of Hypothesis
Null Hypothesis 2	H_0 $\mu_1 = \mu_2$ $= \mu_3 = \mu_4$
	There is no difference in test scores between children who were aided and were not aided by Timez-Attack, where <ul style="list-style-type: none"> μ_1 is the mean test score of boys who were not aided, μ_2 is the mean test score of girls who were not aided, μ_3 is the mean score of boys were aided, μ_4 is the mean scores of girls who were aided.
Alternate Hypothesis 2	Not all four means are equal
	There is a difference in test scores between genders who were aided and were not aided by Timez-Attack, where <ul style="list-style-type: none"> μ_1 is the mean test score of boys who were not aided, μ_2 is the mean test score of girls who were not aided, μ_3 is the mean score of boys were aided, μ_4 is the mean scores of girls who were aided.

A one way ANOVA test was used followed by Tukey's Post Hoc. As the ANOVA showed significant difference, the Tukey test would facilitate which means were different. Table 4 presents the ANOVA test.

TABLE IV
GENDER ANOVA TEST

Source of Variation	SS	df	MS	F	P-value
Between Groups	4649.544	3	1549.848	15.80106	2.29E-08
Within Groups	9023.828	92	98.08509		
Total	13673.37	95			

As $p < .05$, reject H_0

1. Hypothesis:

$$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4$$

H_1 : Not all four means are equal

$$2. \alpha = .05$$

3. Test statistic: F -statistic

4. Decision criteria: Reject H_0 and accept H_1 if p -value $< .05$

5. Calculation: p -value = 2.29E-08

6. Conclusion: Based on the results of this sample and analysis, not all four means are equal.

The Tukey test facilitate which means were different through indication of pairwise p -values. The test compares each pair of data by comparing the means from each row with the means for each column. Table 5 shows that the pair shows a significant difference if the p -value is less than .05,

TABLE V
RESEARCH QUESTION 2 TUKEY TEST

	Girls w/o Game	Boys w/o Game	Girls w/Game	Boys w/Game
Girls w/o Game	15.78125	12.44792	27.29167	28.33333
Boys w/o Game	12.44792	0.073981504		
Girls w/Game	27.29167	5.73795E-05	1.2249E-07	
Boys w/Game	28.33333	0.000135828	1.94204E-08	0.315698

p -value for experiment pairwise error rate: $\alpha = 0.05$

From the Tukey's Post Hoc, the following pairs are significantly different:

- Girls w/o Game versus Girls w/Game
- Girls w/o Game versus Boys w/Game
- Boys w/o Game versus Boys w/Game
- Boys w/o Game versus Girls w/Game

C. Research Question 3

What was the difference in learning achievement of multiplication facts between urban and rural children who were aided by computer-based video game in learning ? Table 6 presents the hypothesis and null hypothesis corresponding to Research question 3.

TABLE VI
HYPOTHESIS (RESEARCH QUESTION 3):EFFECT BY LOCATION

Hypothesis 3	Statement of Hypothesis
Null Hypothesis 3	$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4$ There is no difference in test scores between urban children and rural children who were aided and were not aided by Timez-

Attack, where

- μ_1 is the mean test score of urban children were not aided,
- μ_2 is the mean test score of rural students were not aided,
- μ_3 is the mean score of urban children were aided,
- μ_4 is the mean scores of rural students were aided.

Alternate Hypothesis 3

Not all four means are equal

There is a difference in test scores between between urban children and rural children who were aided and were not aided by Timez-Attack, where

- μ_1 is the mean test score of urban children were not aided,
- μ_2 is the mean test score of rural students were not aided,
- μ_3 is the mean score of urban children were aided,
- μ_4 is the mean scores of rural students were aided.

A one way ANOVA test was used followed by Tukey's Post Hoc. As the ANOVA showed significant difference, the Tukey test would facilitate which means were different. Table 7 presents the ANOVA test.

TABLE VII
LOCATION ANOVA TEST

Source of Variation	SS	Df	MS	F	P-value
Between Groups	5065.215	3	1688.405	18.71026	3.47E-09
Within Groups	6858.203	76	90.23951		
Total	11923.42	79			

As $p < .05$, reject H_0

1. Hypothesis:

$$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4$$

H_1 : Not all four means are equal

$$2. \alpha = .05$$

3. Test statistic: F -statistic

4. Decision criteria: Reject H_0 and accept H_1 if p -value $< .05$

5. Calculation: p -value = 3.47E-09

6. Conclusion: Based on the results of this sample and analysis, not all four means are equal.

The Tukey test facilitate which means were different through indication of pairwise p -values. The test compares each pair of data by comparing the means from each row with the means for each column. Table 8 shows that the pair shows a significant difference if the p -value is less than .05,

TABLE VIII
POST HOC ANALYSIS: TUKEY P-VALUES FOR PAIRWISE T TESTS

		U.S. w/o Game	R.S. w/o Game	U.S. w/ Game	R.S. w/ Game
		9.1875	15.6875	26.06 25	29
U.S w/o	9.1875				
R.S w/o	15.6875	0.004161875			
U.S w/gam	26.0625	9.28403E-06	0.013560149		
R.S w/gam	29	2.26395E-08	2.18806E-05	0.167	

p-value for experiment pairwise error rate: $\alpha = 0.05$

From the Tukey's Post Hoc, the following pairs are significantly different:

- Urban children w/o Game versus Rural children w/o Game
- Urban children w/o Game versus Urban children w/Game
- Urban children w/o Game versus Rural children w/Game
- Rural children w/o Game versus Urban children w/Game
- Rural children w/o Game versus Rural children w/Game

D. Research question 4

What was the difference in learning achievement of multiplication facts among below average, average and above average levels of children who were aided by computer-based video game in learning ?

Table 9 presents the hypothesis and null hypothesis corresponding to Research question 4.

TABLE IX
HYPOTHESIS (RESEARCH QUESTION 4): EFFECT BY ACHIEVEMENT LEVEL OF STUDENTS

Hypothesis 4	Statement of Hypothesis
Null Hypothesis 4	$H_0: \mu_1 = \mu_2 = \mu_3$ There is no difference in test scores among below average, average and above average levels of children who were aided by Timez-Attack, where • μ_1 is the mean test score of below average level children who were aided, • μ_2 is the mean test score of average level children who were aided, • μ_3 is the mean test score of above average level children who were aided.
Alternate Hypothesis 4	Not all three means are equal There is a difference in test scores among below average, average and above average levels of children who were aided by Timez-Attack, where • μ_1 is the mean test score of below average level children who were aided, • μ_2 is the mean test score of average level

children who were aided,
 • μ_3 is the mean test score of above average level children who were aided.

A one way ANOVA test was used followed by Tukey's Post Hoc. As the ANOVA showed significant difference, the Tukey test would facilitate which means were different. Table 10 presents the ANOVA test.

TABLE X
CHILDREN'S ANOVA TEST

Source of Variation	SS	Df	MS	F	P-value
Between Groups	971.9401	2	485.9701	5.712919	0.006152
Within Groups	3827.93	45	85.0651		

As $p < .05$, reject H_0

1. Hypothesis:

$$H_0: \mu_1 = \mu_2 = \mu_3$$

H_1 : Not all three means are equal

2. $\alpha = .05$

3. Test statistic: F-statistic

4. Decision criteria: Reject H_0 and accept H_1 if *p-value* < .05

5. Calculation: *p-value* = 0.006152

6. Conclusion: Based on the results of this sample and analysis, not all three means are equal.

The Tukey test facilitate which means were different through indication of pairwise *p-values*. The test compares each pair of data by comparing the means from each row with the means for each column. Table 5 shows that the pair shows a significant difference if the *p-value* is less than .05,

TABLE XI
POST HOC ANALYSIS: TUKEY P-VALUES FOR PAIRWISE T TESTS

	Below Average	Average	Above average
	23.203125	33.75	25.70313
Below Average	23.203125		
Average	33.75	0.000100315	
Above average	25.70313	0.245503065	0.013974199

p-value for experiment pairwise error rate: $\alpha = 0.05$

From the Tukey's Post Hoc, the following pairs are significantly different:

- Below average versus Average
- Average versus Above average

IV. DISCUSSION OF FINDINGS

The overall purpose of this study was to investigate the effectiveness of complimentary addition of the video game, Timez-Attack, as a supplement to the Mathematics subject of Year 3 at primary school level. Based on the analysis of the data, the following findings are revealed:

1. Research Question 1: Based on the one tail t test in Table 2, the average test score for children who were aided by Timez-Attack was significantly greater than the average test score for children who were not aided by Timez-Attack. Figure 1 shows the means test scores with and without aid of video-game.

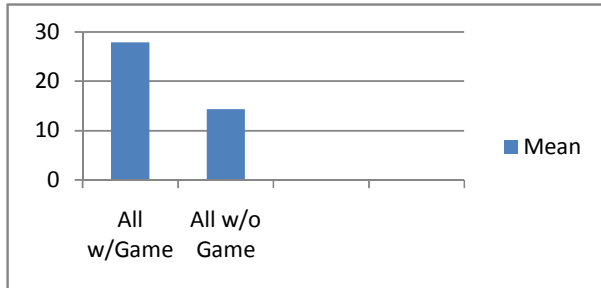


Fig. 1 Average test scores

2. Research Question 2: Based on the one way ANOVA and Tukey test in Table 4 and Table 5, both boys and girls scored significantly higher with game aid than others without game aid. However, there was no significance difference between boys or girls' scores regardless of game aid. Figure 2 shows the means of gender test scores with and without game aid.

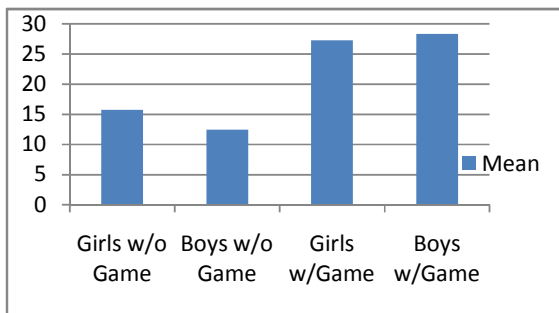


Fig. 2 Boys and Girls, with and without game averages

3. Research Question 3: Based on the one way ANOVA and Tukey test in Table 7 and Table 8, both urban students and rural students scored significantly higher with game aid than those without game aid. However, there was no significance difference between urban children and rural children with regards of game aid. Figure 3 shows the means test scores between urban children and rural children.

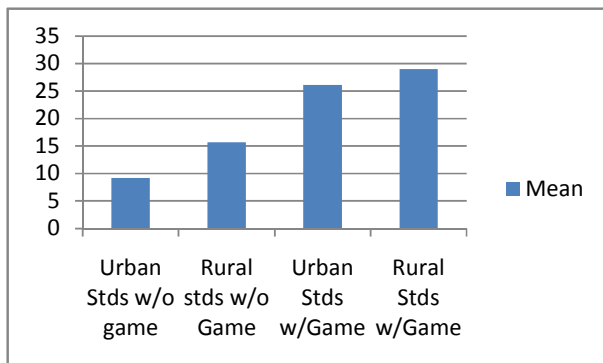


Fig. 3 Urban and rural students, with and without game averages

4. Research Question 4: Based on one way ANOVA and Tukey test in Table 10 and Table 11, there was a significant difference in the mean score between below average students and average students at game play and also between average students and above average students at game play. However, there was no significant difference between below average students and above average students at game play. Figure 3 shows the means test scores among below average, average and above average students who use the game.

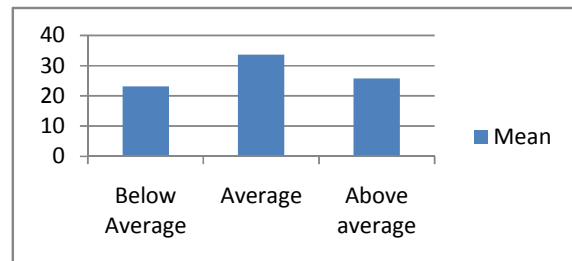


Fig. 4 Below average, average and above average students, with and without game averages

As a conclusion, from the findings of this study, video games as a supplementary activity to classroom learning brings significant and positive effect on students' retention and mastery of multiplication tables as compared to students who rely only upon formal classroom instructions. In terms of gender factor, although male students scored slightly high on average compared to female students, the difference was significant; in other words, gender is not a factor in the implementation of video games as learning activity. When comparing urban students and rural students, although it was interesting to find out that the mean score for rural students were higher compared to urban students, the difference was not significant which suggest that the effect of video game in this study does not depend on learners' geographical status at least for the scope of this study. However, it was interesting to find out that there was a significant difference in terms of mean score among the average learners compared to below average and above average students. It would be a valuable research to find out further in investigating the reasons behind this findings.

V. CONTRIBUTION OF RESEARCH FINDINGS

The study will have its impact on the future curriculum of tomorrow's society to keep the nation abreast with the advancement of technology in education and to be at par with other developed countries which have increasingly embraced the notion of digital game in their education system. The study will not only contribute to video games as future learning tools for the nation of tomorrow but it will also serve as a model or a guide to how video games could affect the teaching and learning in formal education. Education stakeholders, policy makers, teachers, researchers and private sectors could benefit from this study especially in gaining some insights into whether or not to incorporate video games in assisting students learning. As the study reveals that video

games could improve students' learning significantly, educational stakeholders and the education ministry should be prepared early to provide the relevant infrastructures, selection of video games and learning content, management of learning system, or skills and form of training needed for instructors. Nevertheless, further and elaborated research on the use of video games should be conducted to facilitate solid findings before any the final decision is made on incorporating video games in education. This study could also be a model or a guide to be replicated to study the impact of video games on other subject areas such as arts, languages, and sciences and could also be extended to the secondary and tertiary learning levels.

VI. CONCLUSION

This study is undertaken as it is relevant to the current as well as future needs of the nation for sustainable education. The decision made by the researcher in selection of the topic to be studied is also based on consideration of niche research areas in education especially pertaining to technology-enhanced innovation in higher education. Based on the discussion here, it is important for the education stakeholders and the government to consider the possibility of video games as learning tools or an approach of the future and thus be well prepared to brace the impact of this emerging learning mode to our country. As mentioned in this study, under the influence of technology, children of today have been affected largely by technology especially video or computer games and making self initiated decision to turn to this new wave of technology for alternative mode of learning. This resulted in concerned educationists and researchers all over the world to initiate discussions on whether video games should be accepted or banned from formal education. As video games do contribute significantly positive to learning as highlighted in this study, it is a matter of time before video games will be included in mainstream education throughout the world. However, as video games are still debatable in its use in formal education, a number of unsettling issues foreshadow this new learning mode. Among them would be the ongoing debate of how video games impact students learning, how it should be conceptualized, defined, managed and assessed. Thus in this study, the researchers decide to commit to evaluate the use of video games on children's learning.

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