Effect of Curriculum-Based Video Games on Students' Performance

An Experimental Study

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Abstract—This experimental study investigated the effect of the use of video games based on the curriculum on students' performance levels in Fourth, Fifth and Sixth grade Mathematics compared to traditional learning methods. The participants were seven hundred and eighty-nine female students from Fourth, Fifth and Sixth grades, and nineteen teachers, from different six schools in Riyadh city in Saudi Arabia. Three research null hypotheses were tested to explore students' performance when they received two different instructional treatments: traditional learning methods (textbooks or worksheets) and a video game based on the Mathematics curriculum. The results indicate that video games based on Mathematics curriculum had a positively effect on students' performance based on their score average in standard tests, when compared to traditional learning methods.

Keywords—Education, Educational video game, learning methods, Edutainment

1 Introduction

Since ancient times, games have been an important part of human life, not only in childhood, but also during adulthood [1]. Moreover, video games are considered the most popular activity among young people today [2]. Since the advent of video games, they have been seen as a potential educational tool, especially as they are aimed at the current generation of students, who are called the Net-generation [3, 4]. Unfortunately, this generation of students is still being taught using traditional methods that have been around for decades, and which do not suit their needs; moreover, many students see this as boring and slow. This has led to many teachers and researchers attempting to find alternative ways of teaching this generation of students [5, 6]. There are many experimental studies that have proven that video games are an effective learning method. It has been shown that students playing video games perform better than those learning through traditional methods [7, 8]. Video games are no longer seen as entertainment tools only. Several studies have proven that video games are a useful educational tool and are able to enhance students' positive

attitudes towards school and the learning process [6, 9, 10]. Video games provide a good way of embedding curriculum content, such as mathematical and science concepts, which may be difficult to visualise. In addition, they provide a good way of learning languages and geography [11]. There are important arguments about video games and how they provide huge opportunities for teachers to make their topic come alive, and to motivate their students to learn. Video games make studying interesting and enjoyable for students, as well as making the learning environment more aligned with the needs of the students [12, 13]. Educational institutions have started to incorporate technology into the teaching and learning process in an attempt to change teaching and learning practices within schools in order to motivate students to become more active in the learning process [14]. A number of studies have shown the effectiveness of video games in education, with several studies indicating that educational video games provide various benefits to learning, such as engagement and enjoyment, attracting the attention of students, and increasing their motivation. Video games also have a positive impact on student performance, on attitudes towards learning, and on self-conception when compared to traditional learning. Furthermore, where students showed more consistency in the tasks, their performance improved after playing appropriate video games. Moreover, video games encourage active learning and learning by doing. In addition, video games provide immediate feedback, which influences the behaviour and attitude of players [2, 10, 15-19]. An experiment conducted in an Elementary school found that a video game designed to teach the arithmetical order of operation rules improved students' motivation for learning and had a positive effect on the earning process [5]. Furthermore, another study examined the effect of computer games on students' attention and speed in learning math. The participants were first year male students from four public secondary schools in district one of Urmia City in the academic year of 2012-2013. They were assigned randomly to an experimental group and a control group. The experimental group played the free game "Ocean Express" for ten sessions for 45 minutes each. Meanwhile, the control group learnt through traditional methods. The results show that computer games increased the attention and speed of math calculations among the experimental group [20]. In addition, the impact of educational video games on learning was investigated in schools in Chile with a total of 1274 students. The sample was divided into experimental groups, internal control groups and external control groups. Students in the experimental groups used the video games that were designed to achieve the educational objectives of basic language acquisition skills and basic mathematics during the first and second grade. These games were played by the experimental groups for 12 weeks, for 20 to 40 minutes daily during class hours. On the other hand, the control groups did not play video games. The students were evaluated through ad hoc tests and classroom observations. The results show significant differences between the experimental groups and internal control groups in relation to the external control groups in mathematics skills and reading comprehension. Moreover, the results confirm an improvement in attention and motivation to learn in the experimental groups. In addition, the participant teachers praised video games as a positive and effective resource that can support other traditional resources [12]. Another experimental study performed in the US examined

the effects of math games on students' achievements in math, and on the students' motivation. The results show that the scores of the students improved for mathematics. Moreover, according to the findings from the interviews with teachers, they thought that the game used in the study was an effective learning and teaching tool that could help to improve students' achievement [21]. Furthermore, the study showed that a math facts video game for second graders increased motivation to engage in learning activities. The students who played the video game completed three times the number of problems in 19 days compared to those who completed paper worksheets [22, 23]. Hence, empirical studies have shown that video games can be useful tools for enhancing learning, and they are a good tool for making complex subjects more understandable. Furthermore, video games enable players to reach different types of knowledge, and last but not least, video games develop a number of cognitive skills as well as giving a mental workout and encouraging learning outcomes for students in general [24-26]. Such studies have not been absent from a Saudi Arabian perspective. For example, a descriptive study examined the experiences of Saudi teachers with video games and their perceptions towards incorporating these games into classrooms in Saudi Arabia. The results showed that there are no differences between teachers who play video games and those who are non-playing in attitudes towards using video games in the classroom. Moreover, the study results have shown positive attitudes among teachers concerning applying video games in the classroom, even when they are at a low level of play. Furthermore, although females typically play video games less than males, their attitudes have also been shown to be positive regarding using video games in the classroom. In addition, the study indicates that teachers do not need to be gamers to use video games in classrooms [27]. A quantitative study was also conducted in Makkah City in Saudi Arabia for the purpose of examining the experiences of middle school students with video games. This study describes the current state of playing video games and how that has affected the academic grade point average (GPA) of students. The participants in this study were 201 students. The study found a positive relationship between the GPAs of students and the amount of time they play video games [28]. Video games provide a good opportunity for applying knowledge in practice, improving problem solving skills and promoting learning through trial and error [2, 29]. However, evaluating the effect of educational video games on the success of students is an important topic and needs further research [30]. Education is not only something to be told, but a practice and active constructive process [15]. Therefore, combining educational content with children's interests in video games, can lead to an important learning tool inside classroom [31]. As games are part of people's lives at all stages of their development, they should be adopted in schools at an early stage when the need to learn is maximal [13, 32]. In addition, some researchers have argued that most of the elementary curriculum could be more effectively taught through video games [5, 33]. However, it is disappointing to see a general lack of subject matter within video games. Moreover, it is also frustrating that schools often offer games as an incentive for good behaviour (which indicates their recognition that children like to play these games), but fail to use them for educational purposes despite all of the positive results and this potential being recognised [34]. Using video

games as a support for traditional teaching methods is more efficient compared to solely depending on traditional methods of teaching. This is due to students usually preferring video games over traditional classroom media [1, 15]. One study investigated the effect of video games on the success of students compared to traditional lectures alone, and found that students who used computer games were more alert, more involved and their performance was better compared to the traditional approach [35]. Video games have a great ability to turn traditional methods of learning into a more motivational and more entertaining environment. Nevertheless, this is not to say that games should only be used to motivate students - they must be used for teaching educational content and developing interactive and attractive learning environments that map the curriculum appropriately. When video games are viewed as an efficient means to learn more, students will be motivated to use them for learning and not just because they are a game [36, 37]. However, most studies have focused on the pedagogical aspects of video games, and few studies have actually investigated the mechanisms for delivering the games to students. Moreover, the integration of video games with traditional methods is a major problem in delivering these games [38], and we cannot assume that video games will substitute of face-to-face teaching. Nevertheless, it is important to use various teaching tools and practices beside traditional methods in order to facilitate learning and make it more acceptable to students [30]. Video games provide a great chance to apply knowledge in practice, improve problem solving skills and promote learning through trial and error [2, 29]. However, evaluating the effect of educational video games on the success of students is an important topic and needs further research [30]. They must not only be used as an entertainment tool only, but as an educational tool. In Saudi Arabia, the usage of video games as an educational tool is rare and very few articles have discussed this topic. In addition, many research studies have indicated that both males and females generally feel that video games are challenging and fun, and it develops useful skills and knowledge [28, 39]. It has been proven that males typically prefer playing video games more so than females; however, there is evidence that females might enjoy video games more than their male counterparts from the 4th through to the 6th grade [27, 40].

2 Research Aim

This research aims to investigate the effect of the use of video games based on the curriculum on students' performance levels in fourth, fifth and sixth grade Mathematics. In order to accomplish this aim, this study will examine the following hypotheses:

- **Hypothesis 1**: There are no significant differences in the mean scores of Fourth graders in Mathematics between the control and experimental group.
- **Hypothesis 2**: There are no significant differences in the mean scores of Fifth graders in Mathematics between the control and experimental group.
- **Hypothesis 3**: There are no significant differences in the mean scores of Sixth graders in Mathematics between the control and experimental groups.

3 Methodology

The research has used an experimental design. A true experimental design was used, in particular for the pretest and posttest experimental and control group design, which is where the independent variable is manipulated in the experimental group and it stays constant without any manipulation in the control group [41]. In addition, this study is based on convenience sample with a total of 789 students (fourth to sixth grades) and 19 teachers from six different schools in Riyadh city in Saudi Arabia during 2019.

3.1 Variables

Based on the research questions, independent and dependent variables were identified in order to discover how video games based on the curriculum affect students' performance levels. The independent variable is the variable that affects the dependent variable or outcome, while the dependent variable is a characteristic or attribute that is influenced by the independent variable, and it is the researcher's focus [41]. Moreover, there are many variables controlled during an experiment that can have an impact on the relationship between the independent variable and the dependent variable, known as the control variable [42]. Control variables improve the study's efficiency, as any changes that occur to the dependent variable are caused by the independent variable only [43]. In this research, there was only one independent variable which is the teaching method (video games based on the curriculum or a textbook), and one dependent variable, which was students' test scores - the key element of this study. Moreover, a number of variables that may influence the results according to previous studies were controlled, such as teachers' experience of teaching; teachers' experience with video games; time spent playing, and the students' gender [5, 27, 44]. All the participating teachers had experience with video games ranging from one to three years. In addition, the same teacher taught the same lessons to both the experimental group and the control group in order to control the effects that may arise if the teacher taught the lessons to the control group and another teacher taught the experimental group, as they would have different experiences in teaching and different teaching styles. On the other hand, a specific time was allocated for playing educational video games in the classroom. Finally, the differences between genders in how the games affect them were controlled by identifying one gender.

3.2 Video games based on the mathematics curriculum

Education in Saudi Arabia is free at all levels of school: kindergarten, primary school, middle school, high school, and university [45]. The education system in Saudi Arabia is under the authority of the Ministry of Education. The Ministry of Education in Saudi Arabia is responsible for the planning and supervision of education for three educational levels (primary school, middle school, and secondary

school). Primary school includes grades from one to six, middle school is grades seven to nine, and secondary school is grades ten to twelve. The curricula at all levels are standardized throughout the Kingdom [46]. Since the curricula are standardized, it was easy to design video games based on these curricula and that are suitable for all schools. The games were designed based on the Input-Process-Outcome Game Model, which describes the most important inputs and processes of educational games to obtain the required educational outcomes. This model indicates that the educational content must be combined with the characteristics of the game in order to launch the game cycle, which contains the user's reactions and judgment, such as the time spent on a particular mission and the extent of his or her interest in it. It also contains the system feedback. When success is achieved in integrating educational content with the characteristics of the game, this cycle will continue, and so the learning will increase and, in the end, playing these games should lead to achieving the required results [15]. Moreover, one of the benefits of this model is that it allows students to learn through trial and error [47, 48]. It is important that the characteristics of games are the first input in order to motivate the player. These characteristics have been identified by several researchers and they claim that each game must contain a set of characteristics such as a storyline, competitiveness, feedback, and visual and sound content [15, 18, 49]. The integrated educational content with the game's characteristics will attract the player's attention to these games and encourage them to get involved in them, which will generate certain reactions such as interest and enjoyment. In addition, the immediate feedback that shows the players their progress in the game will encourage them to perform better, which should result in achieving the educational goals required [20, 50, 51]. These video games have been used as a substitute for textbooks and worksheets to practice the acquired skills, since educational video games based on drill and practice increase students' achievement. The games have been designed based on this approach, in order to have a positive effect on student performance [52, 53]. The games have been designed as an adventure where a main character is controlled by the player. This character faces some challenges that require performing certain tasks. An adventure mode and a main character were used to motivate students to play this game because this type of game has been found to be preferred by girls [30, 54]. The video game begins with a short story followed by the game's instructions, and then some tasks are assigned to the player. In addition, there is a specific timeframe for each task to be completed within. After every task that the player completes correctly before the end of the timeframe, they are given feedback to enhance their performance, and they are given a word. If they answer all the tasks correctly, they will have succeeded in the game and obtained the secret sentence, and all they must to do now is tell their teacher the secret sentence. This approach increases the spirit of competition and challenge among players, as each player wants to attain the secret sentence first. On the other hand, if the player makes wrong choices or if time of the task ends before they have completed the task, an alert message will be shown and the game will start again (see Figure 1).

Fig. 1. Video games based on curriculum

3.3 Experimental procedure

Before the experiment began, the necessary software was installed on computers in the schools. The students were also randomly assigned to the experimental group and the control group. Video games were used for eight different Mathematics lessons by all classes (Fourth grade, Fifth grade and Sixth grade). Each grade had its own video game based on curriculum. The teachers explained the lessons in the traditional way for a period that did not exceeding twenty minutes. After that teacher gave both groups a short 4-point test that did not exceeding eight minutes to measure students' performance as a pre-test. Then the teacher allowed the experimental group to play the video games for a period of time that did not exceed nine minutes, while the control group used the traditional method to practice the new skills by completing worksheet or textbook activities. Then another short 4-point test was distributed to the two groups as a post-test. The short 4-point test that was used to measure student performance is a standardised test built by all participating teachers based on school textbooks. This measure is considered reliable and valid since it was designed using the questions at the end of chapters in the school textbooks, which were developed by educational experts and university professors with scientific and professional experience and based on a reliable sources [46]. After all the lessons were completed, the students' grades were collected from the teachers.

4 Findings and Discussion

To test significant differences in students' performance among the control group and experimental group, an independent samples t-test was performed using Statistical Package for the Social Sciences (SPSS). The null hypothesis was rejected at a significance level of 0.05 ($p \leq 0.05$). The independent samples t-test was used to compare the mean of one variable between groups in the variable of interest [41]. It was used to examine the effect of categorical variables (treatments) on

interval/dependent variables (students' scores). Moreover, the data was examined and it was found that it was normally distributed with no outliers. In addition, Levene's test of equality of error variances was used, and the results show that the dependent variables had equal variance ($p > .05$). Based on the above, an independent samples t-test could be conducted for data analysis. To test the first hypothesis, an independent samples t-test was used to indicate any significant differences between the control and experimental groups in the Fourth grade. Independent samples t-test was performed to compare the test scores between the control group and the experimental group. It was found that there was no significant difference ($p = 0.240$) for the pre-test between the control group ($M = 21.08$, $SD = 2.795$) and the experimental group ($M = 20.66$, $SD = 2.952$). On the other hand, independent samples t-test for the post-test found a significant difference ($p = 0.003$) between the control group ($M = 23.73$, $SD = 2.341$) and experimental group mean ($M = 24.56$, $SD = 2.239$) in the benefit of the experimental group (see Table 1). Accordingly, the null hypothesis was rejected and the alternative hypothesis accepted, which indicates that there are significant differences in the mean scores of Fourth graders in Mathematics between the control and experimental groups.

Table 1. Independent-samples t-test result of the pre-test and post-test for Fourth grade students in Mathematics

Independent Samples Test						
		Levene's Test for Equality of Variances		***t-test for Equality of Means***		
		F	***Sig.***	***t***	***df***	***Sig. (2-tailed)***
PreTest	Equal variances assumed	.479	.490	1.178	262	.240
PostTest	Equal variances assumed	.101	.751	-2.956-	262	.003

For the second hypothesis, another independent samples t-test was performed. No statistically significant difference ($p = 0.510$) in the pre-test was found between the control group ($M = 23.14$, $SD = 3.787$) and the experimental group ($M = 23.43$, $SD = 3.150$). On the other hand, independent samples t-test for the post-test found a statistically significant difference ($p < 0.001$) between the control group ($M = 24.17$, $SD = 2.770$) and the experimental group mean ($M = 25.34$, $SD = 2.359$) in the benefit of the experimental group (see Table 2).

Table 2. Independent-samples t-test result of the pre-test and post-test for Fifth grade students in Mathematics

Independent Samples Test						
		Levene's Test for Equality of Variances		***t-test for Equality of Means***		
		F	***Sig.***	***t***	***df***	***Sig. (2-tailed)***
PreTest	Equal variances assumed	3.150	.077	-.660-	261	.510
PostTest	Equal variances assumed	2.610	.107	-3.684-	261	.000

Accordingly, the null hypothesis was rejected and the alternative hypothesis was accepted, which indicates that there are significant differences in the mean scores of Fifth graders in Mathematics between the control and experimental groups.

For the third hypothesis, independent samples t-test was performed. This showed no statistically significant difference ($p = 0.231$) in the pre-test between the control group ($M = 21.07$, $SD = 2.804$) and the experimental group ($M = 20.64$, $SD = 2.956$). On the other hand, independent samples t-test for the post-test found a statistically significant difference ($p < 0.001$) between the control group ($M = 23.61$, $SD = 2.309$) and the experimental group mean ($M = 24.92$, $SD = 2.631$) in the benefit of the experimental group (see Table 3).

Table 3. Independent-samples t-test result of the pre-test and post-test for Sixth grade students in Mathematics

Independent Samples Test						
		Levene's Test for Equality of Variances		***t-test for Equality of Means***		
		F	***Sig.***	***t***	***df***	***Sig. (2-tailed)***
PreTest	Equal variances assumed	.420	.518	1.201	260	.231
PostTest	Equal variances assumed	1.616	.205	-4.268-	260	.000

As a result, the null hypothesis was rejected and the alternative hypothesis accepted, which indicates that there are significant differences in the mean scores of Sixth graders in Mathematics between the control and experimental groups.

5 Summary and Conclusion

The aim of this study was to investigate the effect of the use of video games based on the school curriculum on students' performance levels in fourth, fifth and sixth grade Mathematics. The independent samples t-test was used to test all of the research hypotheses, to determine whether there were statistically significant differences between the control groups and experiment groups. The differences between the groups were measured before and after the treatment in order to determine its effects accurately. The results show that there were no statistically significant differences between the groups in the pre-test, but differences between the groups appeared in the post-test. In general, the results of this experiment show a positive effect from video games based on the school curriculum on student's performance in Mathematics compared to traditional methods alone. This result is in agreement with other studies that showed the positive effect on students' performance after using educational video games [21, 22, 28, 55]. Moreover, the teachers noticed that students playing video games are more alert and interactive in the classroom; in addition, they became more excited to learn. This result is not surprising, as many studies have proven this as well [56, 57], although little research has been conducted in a Saudi context. The learning method that relied on the video games based on the curriculum was not used as a substitute for the role of the teacher in the classroom, but it was used as a tool to

support traditional teaching methods. This is important, since many research studies have indicated that video games may be an alternative to textbooks and science laboratories in order to practice the required skills, but they cannot be a substitute for a teacher [1, 9, 58, 59]. The integration of video games based on the school curriculum, along with traditional teaching methods, is an encouraging factor for changing pedagogical practices. The results of this study indicate that it is important to review current teaching methods and replace them with other methods that suit the current generation of students and facilitate their education. Moreover, video games are not only for fun, as they may also be effective as educational tools, especially if they are based on the curriculum [12]. Additionally, this research may contribute to a broader acceptance of educational video games because of its evidence for their positive effect on student success and classroom activities.

6 References

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