The Effectiveness of Educational Games as Part of K-12 Curricula

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Abstract

This paper explores numerous studies about educational games, emphasizing the effectiveness of games as teaching tools for various subject areas. First, we examine the results of studies that test the effectiveness of games designed to teach memory and retention. Then we examine studies that test the effectiveness of games designed to teach and encourage STEM-related subjects. With a deep understanding of the different uses for educational games, we suggest areas in which further research is required to better understand how video games fit into the classroom. We also form guidelines for developers who are designing serious games to teach K-12 curricula.

Keywords: Video games, Serious games, Educational games, Education, K-12, Memory, STEM

Introduction

The growing presence of personal computers and game consoles has led people to spend more time interacting with electronic media than ever before. As such, video games have become a very common form of entertainment for many school-aged children (Young et al., 2012). Educators have begun to take advantage of this medium to serve a different purpose than purely entertainment. Serious games, or games that have a specific purpose or message, are becoming more widely accepted as tools for education. However, it is essential to analyze the effectiveness of educational games in order to best improve teaching of K-12 curricula.

Though some educators use video games to aid in their quest to spread knowledge and insight, video games still are not widely used for teaching. In 2003, educational video games accounted for only 1% of the PC gaming market. This is possibly due to the fact that most of these educational games are produced by universities on limited budgets (Moshirnia et al., 2010). It's also possible that video games possess a stigma of violence and sexism that causes skepticism of their place in the classroom (Barko & Sadler, 2012). Regardless, this lack of popularity has caused the education field to conduct very little research and possibly to overlook a tool that could be essential to teaching children in an increasingly technological era.

Video games spur more motivation in children than other mediums because they utilize a unique combination of visual communication and interaction. This leads to students becoming more engaged and interested in the material being presented to them (Buchanan & Elzen, 2012). In fact, one study noted that continued exposure to science games led students to become highly engaged and to pursue STEM (Science, Technology, Engineering, and Math) careers (Anetta et al., 2014). Still, increased motivation alone does not make educational games effective tools.

In this paper, we will review several studies about educational games, emphasizing the effectiveness of games as teaching tools for various subject areas.

Effectiveness for Memory and Retention

Application to K-12 Curricula

Almost all subject areas of the K-12 Curricula involve memory and retention. Areas such as history, humanities, and biology especially utilize these skills, with students having to process and retain large amounts of information.

Research Studies

Several studies have been conducted to test the efficacy of serious games in improving players' memory and retention.

A. *Genomics Digital Lab*

Muehrer et al. conducted a study to test the effectiveness of a biology game called *Genomics Digital Lab* on student retention.

Figure 1. A screenshot of *Genomics Digital Lab* showing the ability of the player to control various aspects of a plant's life in order to experience the outcome (Muehrer et al. 2012).

As can be seen in Figure 1, the player is given several environmental controls that affect the life of the plant in the game. By allowing students grade 7-12 to adjust these factors and experiment with the results, the game teaches students about plant cell anatomy and photosynthesis.

161 students participated in the study, and 147 completed quizzes before and after a one-hour session of playing the game. The researchers found that the game had a generally positive impact on retention of information presented. Approximately 53% of students scored higher on the quiz after playing the game, and most of them were more engaged in the subject matter. It's important to note that there was a correlation between prior knowledge and improvement in quiz score, indicating that the game is more effective as a review tool than as an introduction to the subject matter.

B. CAI vs. Video Games

Chuang and Chen conducted a study that tested the efficacies of both computer-assisted instruction (CAI) and computer-based video games in fact/recall processes. 108 third-graders from Taiwan participated in the study, taking one test before and one test after playing the games. The test involved multiple-choice, matching, and application questions, which tested basic memory recall as well as retention and understanding of information.

Table 1. The mean scores of the participants of the study for each part of the test (Chuan & Chen 2009).

	Treatment groups	Mean
Part 1 (0 – 64 points)	Web CAI	48.842
	Video Game	52.235
	Total	50.444
Part 2 (0 – 18 points)	Web CAI	10.737
	Video Game	11.706
	Total	11.194
Part 3 (0 – 18 points)	Web CAI	10.474
	Video Game	12.235
	Total	11.306
Post-test total score (0 – 100 points)	Web CAI	70.053
	Video Game	76.177
	Total	72.944

The researchers found that the video game had a significantly more positive effect on the students' recall abilities. As seen in Table 1, the CAI group scored a total mean of 70.05 and the video game group scored a total mean of 76.18. Additionally, the video game promoted more problem-solving skills, with students gaining the ability to recognize different solutions for problems. Also, students who scored better before playing the game (i.e. students who already had some knowledge for the application questions) performed significantly better on the application section. This suggests that video games have more of an effect on retention than simple text-based instruction programs through their visuals and interactivity, and that they have a greater effect when the player has some prior knowledge.

C. Digit Span Test

In a study conducted by Garcia et al., 275 Chilean seventh graders were asked about their computer game usage and subsequently took a digit span test. The digit span test served as an assessment of the student's working memory, or ability to hold and manipulate information.

The researchers found that higher scores on the digit span test correlated with students who identified themselves as PC and Console Gamers. There are a lot of factors in this experiment that couldn't be held constant, but the researchers propose a few possible reasons for the correlation between working memory and video game usage. It is possible that the causation is in reverse; i.e. those with better working memory tend to play video games. It's also possible that video games affect multitasking ability, which affects working memory skills. Still, there is the possibility that video games have a direct effect on working memory capabilities.

Analysis of Studies

Though all three studies show generally positive correlations between video games and memory / retention, the correlations are neither consistent nor positive enough to conclude that serious games are effective tools for improving memory. There are several factors that can change the results of a study. For example, the game that is played, the tests that are taken by the participants, and the other factors that can't be controlled can all affect the results.

Overall, it is clear from the studies that video games can have a positive impact on memory, though this impact may not be direct and can depend on many factors. Both studies A and B indicate that video games have a greater positive effect when students begin with some prior

knowledge on the subject matter. This is incredibly important because it indicates that video games are more effective educational tools when they reinforce or reiterate information that students already have encountered.

Effectiveness for STEM

Research Studies

A. The Mediation Effect

Kerr and Chung conducted a study in 2012 about video games' effectiveness in teaching fractions. They also attempted to remove some of the challenges that have hindered similar past studies. The major problem is that there are many factors that the researchers cannot control, like prior knowledge and in-game performance. Thus, it is very difficult to tell if it is the game that is directly causing the results to change, or if the change is simply caused by one of the uncontrollable external factors.

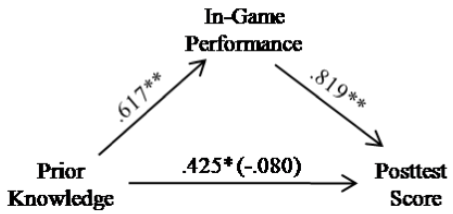

Figure 2. Mediating effect of in-game performance (Kerr & Chung, 2012).

By quantifying each external factor and seeing the relationships between them, it is possible to determine the effect that only the game itself has on the final result. As seen in Figure 2, isolating the effect that prior knowledge has on posttest score enables the ability to calculate the effect that the game has on the result.

Though the sample size in the study was quite small (17 participants), Kerr and Chung found that prior knowledge significantly affects in-game performance, and in-game performance significantly affects posttest score. Thus, they concluded that learning does occur in games and this learning is greater if the student has greater prior knowledge. The game is not effective if the student does not have prior knowledge.

B. MEGA

Annetta et al. conducted a study that tested a teacher created Multiplayer Educational Gaming Application (MEGA) and its effects on students' knowledge of genetics. The researchers assume that because the teacher created the game, it is likely to align more closely with the class curriculum.

The results of the study showed that the video game did not have a positive effect on the understanding of the genetics concepts presented. However, participants were significantly more engaged in the topics while playing the game.

Analysis of Studies

At this time, there is very little research indicating that games can be an effective tool for teaching STEM-related concepts. Study A's results do sufficiently indicate that games can be effective in teaching fractions. Thus, it is not impossible that games can effectively teach STEM topics. However, because this is one of very few studies that got any definitive results at all and other studies produced opposing results, much more research must be done before this new technology is implemented in classrooms.

It is significant to note that Study A found that games are much more effective when players have prior knowledge. This can be related back to Studies A and B in the Memory and Retention section, which both produced the same finding.

There are several research papers indicating that more research must be done before games can begin to teach these topics. Girard et al. states that there is simply not enough research on games' effectiveness in learning. Eck et al. suggest a focus on using games to educate teachers rather than directly having students play the games. Biles indicates that game designers must step back and focus more on how aspects of the game should inform the initial game design before they can begin to be implemented as teaching tools.

Conclusion

This paper reviewed several studies about educational games, emphasizing the effectiveness of games as teaching tools. The studies presented in this paper clearly indicate that it is possible for games to be effective tools for teaching K-12 curricula. However, the mixed results of the studies indicate that much more research must be done to optimize the efficacy of these games.

At this time, games are more successful in teaching memory- or retention-related concepts than in teaching STEM. Several studies have shown a significant improvement in retention of information as a result of games. On the other hand, research into games' efficacy in the STEM field is limited and inconsistent, indicating that STEM games are not yet ready to be implemented in the classroom.

Regardless of what the game is teaching, it is clear that the players' prior knowledge is a significant factor into how effective the game is. Educators must keep this in mind when trying to introduce games into their classrooms. Games may not be able to teach new topics effectively, but it is possible that they are very strong in reinforcing topics that students have already learned.

Game developers who seek to create educational games must begin by reviewing serious games that have successfully achieved their teaching goals. Because every game is different, the developers must then conduct their own research to discover whether their games are effective. Once it is shown that the game successfully teaches students or reiterates a topic they previously learned, the game may be used in classrooms to assist in teaching K-12 curriculum.

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REFLECTION

1. Three of my sources' studies had the same specific finding that none of them highlighted in their abstracts. This was the finding that the educational game was much more effective in teaching when the player already had some prior knowledge of the material in the game. I believe this is an absolutely vital finding that must be kept in mind when implementing these games in the classroom. I mentioned this commonality in three places in my paper: the analysis section of memory and retention, the analysis section of STEM, and the conclusion. "It is significant to note that Study A found that games are much more effective when players have prior knowledge. This can be related back to Studies A and B in the Memory and Retention section, which both produced the same finding… Games may not be able to teach new topics effectively, but it is possible that they are very strong in reinforcing topics that students have already learned."

   There was a debate between several of my sources about the effectiveness of games in teaching STEM. I stated both sides clearly and produced my own synthesis in the analysis section. For example, "because this is one of very few studies that got any definitive results at all and other studies produced opposing results, much more research must be done before this new technology is implemented in classrooms."

2. I emphasized in my synthesis that games are more effective in teaching memory-related concepts than they are in teaching STEM-related concepts. Another professional may disagree, but the numerous studies and evidence provided in the body of my paper strongly support my statement (I explained 3 cases in which memory-related games were successful and was only able to find 1 case in which a STEM-related game was successful). Also, it soon becomes clear that the purpose of my paper isn't to dismiss certain types of educational games, but rather to advocate for further research so that these types of games can become more effective. I show this by providing general guidelines for game developers who seek to create educational games. "Game developers who seek to create educational games must begin by reviewing serious games that have successfully achieved their teaching goals." My advocacy for making educational games better is surely a goal that nobody in the field will dispute.