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Improving mathematics performance by using a videogame style points-based feedback system with elementary school students

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Abstract
Researchers have found that using videogame-based learning has not only led students to be more engaged in the classroom, but also perform better on exams. These researchers have generally focused on variables such as design of content and interactivity for the video games themselves. The present paper looks whether implementing a videogame style points-based system and leaderboard within mathematics software will also improve performance compared to software that simply tells students whether they get the right or wrong answer, as is the case in most educational software products. Participants were 40 4th and 5th graders from Manchirevula Government School and Bhiragiguda Government School in India. They were first taught two- and three-digit multiplication and were randomly assigned to use either the points-based or the non-points-based version of the software. The results show that the students who used the points-based version answered more questions correctly on average compared to the students who used the non-points-based version. Results suggest that the points and leaderboard motivate the students to perform better, suggesting an easy and inexpensive way to boost educational achievement.

Keywords: suggesting, motivate, educational, Government

1. Introduction

Scientists have studied the effects of educational videogames on students' academic performance. Much of the research shows that videogames can boost the motivation to learn and increase comprehension of concepts. One such study was conducted by Ricardo Rosas, Miguel Nussbaum, Patricio Cumsille, Vladimir Marianov, Monica Correa, Patricia Flores, Valeska Grau, Francisca Lagos, Ximena Lopez, Veronica Lopez, Patricio Rodriguez, and Marcela Salinas (2003). The main objective of the study was to evaluate the effects of the introduction of educational videogames into 1st and 2nd grade classrooms on learning, motivation, and classroom dynamics. These effects were studied using a sample of 1274 students from economically disadvantaged schools in Chile. The videogames were specifically designed to meet the educational goals of the 1st and 2nd grade classrooms for basic arithmetic and reading comprehension. The sample group was divided into experimental groups (EG), internal control groups (IC), and external control groups (EC). Students in the EG groups, used the experimental video games during an average 30 hours over a 3-month period. They were evaluated on their mastery of basic arithmetic, reading comprehension, and spelling skills, as well as the motivation to use the educational video games. Teachers' expectations of change due to the use of video games, their technological transfer, and handling of the classroom, were assessed through tests and classroom observations. The results show significant differences between the EG and IC groups in relation to the EC group in math, reading comprehension, and spelling, but no significant differences in these aspects were found between the EG and the IC groups. Teacher reports and classroom observations confirm an improvement in motivation to learn, and a positive technological transfer of the experimental tool.

Also, educational video games can increase engagement and interest in a particular topic. This is showcased in a quasi-experimental study done by Leonard A. Annetta, James Minogue, Shawn Y. Holmes, and Meng-Tzu Cheng (2009) [1]. The study evaluated a teacher-created videogame on genetics in terms of its affective and cognitive impact on student users. While the statistical results showed no differences in student learning, there were significant differences found in the participants' level of engagement while using the video game.

While videogames have been viewed as a promising tool for education, students themselves have their different perceptions on the matter. This is highlighted in the study done by Jeroen Bourgonjon, Martin Valcke, Ronald Soetaert, and Tammy Schellens (2010) [3]. In this study, a path model to examine and predict student acceptance of videogames was used, and empirically tested by involving 858 secondary school students. The results show that students' preference for using video games is affected by a number of factors: the perceptions of students regarding the usefulness, ease of use, learning opportunities, and personal experience with videogames in general. Gender effects are found as well but appear to be mediated by experience and ease of use.

In the US, many students see mathematics as a boring topic that does not apply to real life. Researchers see videogames as tools for helping create interest in mathematics and increasing performance in mathematics. This is shown in the study done by Feng Feng Ke and Barbara Grabowski (2006) [7]. The study observed the effects of videogames on fifth graders' performance and attitudes in mathematics. 125 fifth graders participated in a Teams-Games-Tournament, interpersonal competitive or no game-playing condition. A state standard math exam and survey on attitudes towards mathematics were used for the pretest and posttest. The students' gender, socio-economic status, and prior mathematics ability were examined as the moderating variable and covariate. Multivariate analysis of covariance indicated that the video games were more effective than mathematics worksheets in increasing mathematics performance. Cooperative game playing was the most effective for promoting a positive attitude towards mathematics, regardless of the students' differences.

Although videogames have been seen as a positive way to improve students' learning ability, there is a lack of empirical research on differential effects of computer games on diverse learners. In response to this, a study was done by Sunha Kim and Mido Chang (2010) [9]. The study empirically examined the effects of computer games on math performance on 4th graders, with special focus on gender and language minority groups. The study used the 2005 National Assessment of Educational Progress, a nationally representative database of American students. The study performed regression analyses using more than 170,000 US 4th-grade students by applying a proper weight and considering design effects to have high generalizability. The study used three models for analyses: ELL Model, Gender Model, and Interaction Model. The results show that English-speaking students who played computer math games in school every day showed significantly lower math achievement than those who never played. Contrastingly, positive effects of daily computer use were noted among male students who first language was not English. Male language minority students who played computer games daily in math demonstrated higher math performance scores compared with their English-speaking counterparts who never played.

However, there is a study that showed a completely different results of the effects of prior mathematics knowledge, computer skills, and English skills (Kebritchi, Hirumi, & Bai, 2010) [8]. This study examined the effects of a computer game on students' mathematics achievement and motivation, and the role of prior mathematics knowledge, computer skill, and English language skill on their achievement and motivation as they played the game. A total of 193 students and 10 teachers participated in this study. The teachers were randomly assigned to experimental and control groups. A mixed method of quantitative and interviews were used with Multivariate Analysis of Covariance to analyze the data. The results indicated significant improvement of the achievement of the experimental versus control groups. No significant improvement was found in the motivation of the groups. Students who played the games in their classrooms and school labs reported greater motivation compared to the ones who played the games only in the school labs. Prior knowledge, computer skills, and English skills did not play significant roles in achievement and motivation of the experimental group.

The effects of reward systems on students' motivation to learn has been studied for the last few decades. There was a study done to observe the effects of reward systems by John A. Bates (1979) [2]. The research was critiqued from four theoretical perspectives: self-perception, personal causation, the over justification hypothesis, and behavioral contrast. Studies were grouped according to the independent variables (reward systems) demonstrated to have the greatest effects on subsequent motivation. General trends observed of the results of the research included detrimental effects both of participation-contingent and of task-inherent rewards, and the motivational value of unambiguous social reinforcers.

There have also been studies on the effects of rewards while playing educational videogames. There was a study done to observe the effects of awards by Michael Filsecker, Daniel Thomas Hickey (2014) [6]. The study investigated the effects of external awards on fifth graders' motivation, engagement, and learning while playing an educational game. Researchers were interested in seeing whether the feedback of the game could reduce the predicted negative effects of external rewards. Data of students' engagement and learning were collected and analyzed at multiple levels. A quasi-experimental design was used to observe the effect of external rewards in one group compared to a control group without rewards. According to the results, the external rewards did not weaken the students' motivation. However, they did not foster disciplinary engagement. On the other hand, students in the experimental group (with the external rewards) showed significantly increased conceptual understanding and non-significantly larger gains in achievement.

There is also research based on game-based learning for improving learning (Ching-Hsue Cheng, Chung-Ho Su, 2011) [4]. Cheng and Su used a course's content and mapped it onto a game and used this game to teach the course. The game used 3D development tools. They also used a questionnaire to assess the student's abilities. The students were able to improve their self-efficacy. There is also a social gamification framework for a K-6 learning platform (Simoes, Redondo & Vilas, 2012) [11]. They created social based games for elementary schoolers and found positive results. There is also research for perceptual based learning video game with visual benefits (Jenni Deveau, Gary Lovcik, Aaron R Seitz, 2014) [5].

The present study seeks to investigate a particular feature of videogames, the points awarded for successful performance, as a means of boosting student achievement. Given that research on videogames and rewards both suggest that each can contribute to improved student performance, the present research seeks to tease out whether awarding points for performance is, by itself, sufficient to boost student performance. This is intriguing since points have no inherent value other than to provide an indication of success. Arguably, the same applies to informing students of whether they got the right or wrong answers questions, something inherent in virtually every educational setting. Consequently, points, applied to education, seem almost placebic at best, yet it is hard to imagine youngsters being so ardent about playing videogames if points were not awarded. Related to this, is the notion of a leaderboard, where players see their relative rankings based on the points they earned. Again, it is easy to imagine how youngsters increase their efforts in playing videogames in order to increase their standings on the leaderboard.

Accordingly, the present study's hypothesis is that students who use software that awards points and displays student rankings on a leaderboard will result in higher performance than software that simply provides feedback on whether the student gets the correct or incorrect answer to problems.

2. Method

2.1 Participants

Participants were 40 4th and 5th grade students from Manchirevula Government School and Bhiragiguda Government School in India. There were 25 girls and 15 boys tested. The participants were at a slightly lower level educationally than typical 4th and 5th graders. This was because the participants came from nearby villages, and there is no push for the students to get educated, so they do not go to school on a daily basis. Because of this, the experimenter needed to make sure that all the students knew two-digit multiplication and three-digit multiplication. Since there were 3 laptops used for this experiment, each with the math software, the participants had to learn how to use laptops, since they were not accustomed to using them.

2.2 Description of Software

The software was written in Java. There are two versions. One copy awards points to students who give correct answers and has a leaderboard showing the highest scores and one copy just tells the student whether his or her answer is right or wrong but does not award points or display overall results. Both versions present students with two-digit and three-digit multiplication problems. Because students were taught two-digit and three-digit multiplication in school, both versions of the software can be viewed as practice or homework applications rather than instructional software. Both copies request the user to input the answer in a text box. Both copies have 20 problems that are selected randomly from a set of 300 questions for each iteration of the game, so that each user gets a different set of questions. The copy with points gives the user 100 points per question, so that the user would be motivated to answer more questions correctly. The copy with points creates a leaderboard at the end of the game and shows how the user performed compared to everyone else in terms of points earned. In the non-points-based copy, at the end of the game, the amount of questions that the user got correct is displayed.

2.3 Procedure

This experiment was conducted in a one-day session. Students were tested in groups of three as three computers were available. However, to prevent students from copying answers from each other, each student was given a total of 20 questions that were randomly selected from a pool of 300 questions, thus creating a different problem set per student. There were 2 software versions used, one with points and a leaderboard and one telling only if the user got the question right or wrong and showing the total amount of correct answers. The students were picked at random for which software copy they used. The points-based copy of the software asked for a user name. The points-based copy awarded 100 points per correct answer. Once the session was completed, a leaderboard was displayed, which showed the student's user name and total number of points. This points and leaderboard were expected to motivate students to perform better in mathematics. The non-points-based copy of the software asked for a user name as well but was just used for future reference for data analysis. For each correct answer, the student was told if he was right or wrong. Once the iteration is completed, the total amount of questions that the user got correct was displayed along with the student's username.

3. Results

The participants were graded on a basis of 100 points per correct answer. Given that there were 20 questions presented to each student, a maximum of 2000 points were possible. As seen in Table 1, the average score for the participants in the points-based copy of the software was 1450 points, which means that the participants got an average of 14.5 questions correct. For the participants in the non-points-based copy of the software, the average score was 1150 points, which means that the participants got an average of 11.5 questions correct. This difference was statistically significant $t = 2.44$, $DF = 38$, $p = .02$.

Table 1: Mean Score on Video game based on Correct Answers

Software with Points	Software without Points
1450	1150

4. Discussion

The results confirmed the hypothesis that a points-based system and leaderboard could help students perform better on mathematics problem solving. The students were awarded 100 points for every question they answered correctly, which may have been a factor in motivating students to earn more points, thereby motivating students to perform better on the problems themselves. Also, the leaderboard showed how students performed against the rest of their group, which may have also motivated students. The results may represent an easy and virtually free way to improve student performance in schools. While schools do provide students with grades to indicate performance, grades tend to not have the immediacy that videogame-style points do. It may not be necessary to employ software in order to use the concept of awarding points. Teachers could award points for each correct answer in school (whether it be for classroom participation/assignments, homework or quizzes and tests) and give students a running total of how many points they have earned each quarter or semester. A leaderboard may or may not be provided based on the privacy policies of each school.

Although the leaderboard and points-based system may have been a motivator for students, they did have at least some mastery over multiplication, since they were taught beforehand two and three-digit multiplication. It would be interesting to apply the points-based system and leaderboard to a different videogame that has different mathematical topics such as complex numbers and integrals as these students advance through grade levels. The results gained through this research may have implications not only for the traditional classroom setting, but also outside the traditional classroom setting. As noted in the introduction, the primary method of education in the traditional classroom setting relies on teachers and textbooks for delivering concepts and reinforcing these concepts through a series of worksheets and homework sheets. Normally, all students learn the same material. However, the students learn at different rates that one teacher cannot accommodate. The present results suggest that the students can perform mathematics better with different motivators, as well as some mastery of a certain topic. Many schools have many laptops or other devices, and the teachers could point the students to use the laptops and play different educational videogames to reinforce concepts learned in class, and could also be used to learn concepts as well. Teachers could still review student's work and help them, since the students sometimes could not be able to learn or reinforce concept through video games. Outcomes of this system could help all types of students to learn different concepts.

5. Conclusion

As noted in the introduction, many students around the world are not engaged while in a traditional classroom setting, due to flawed curricula, uninterested teachers, and many other factors. Researchers are investigating and creating new ways to keep students' engagement in the traditional classroom setting, by examining different variables to motivate students to perform better, as well as creating new systems such as videogames or interactive curricula to help students to perform better. Their findings suggest that interactivity and different motivators can help students to perform better compared to traditional classroom instruction.

The present findings suggest that students are able to perform better with different motivators such as a points-based system, leaderboard, and a time counter, as well as having a video game format, which may have seemed to the students as interesting. The points-based systems and leaderboard motivated students to perform better than their peers who had previously played an iteration of the video game. The time counter also motivated students to perform as quickly and accurately as possible.

A second area of research is using AI as an educational tool can be applied to educational video games to help students learn and perform better. AI is an active area of research these days and its application to educational video games has considerable promise. For example, WL Johnson, HH Vilhjálmsson, S Marsella (2005), use the Tactical Language Training System (TLTS), a program that supports rapid acquisition of foreign language and cultural skills. The TLTS combines game design and game development tools with learner modelling, pedagogical agents, and pedagogical dramas. Learners interact in a simulated world with different characters. A virtual aide assists the learners if they experience any difficulty, and gives performance feedback in the context of exercises. AI played a key role in controlling the characters of the game; intelligent tutoring provided supplementary scaffolding. They found that this system was sufficient in providing participants in a more interactive learning experience.

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