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# Improving Mathematics Performance in Algebra by Using A Videogame Style Points-Based Feedback System

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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 follows up our previous research (Somayyajula, Gajula and Leddo, 2019) that shows that awarding points for correct solutions to math problems boosted performance in elementary school students. In the present study, we performed a similar intervention with middle and high school students who solved algebra problems. A total of 28 Participants were asked to solve 20 algebra problems involving mixtures (an application of systems of linear equations) that were delivered via software. Two versions of the software were used. In one version, Participants were told simply whether they gave the correct answer after each problem. In the other, Participants were not only told whether they gave the correct answer but were also given 100 points for each correct answer and shown their cumulative point totals. Participants who received points scored, on average, 47% higher than those who received no points. Results extend our previous work and suggest that the points motivated the Participants to perform better, suggesting an easy and inexpensive way to boost educational achievement.*

## 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

  

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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 videogames 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 videogames. 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 videogames 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). 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 videogame.

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). 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 Fengfeng Ke and Barbara Grabowski(2006). 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,

  

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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). 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 everyday 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). 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). The research was critiqued from four theoretical perspectives: self-perception,

  

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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 and Daniel Thomas Hickey(2014). 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). Cheng and Su used a course's content and mapped it onto a gameand 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). They created social based games for elementary schoolers and found positive results. There is also research for perceptual based learning videogame with visual benefits(Jenni Deveau, Gary Lovcik, Aaron R Seitz, 2014).

In a previous study, we investigated the application of one aspect of videogame playing, awarding points for successful outcomes, on problem solving performance (Somayyajula, Gajula and Leddo, 2019). In that study, two groups of $4^{th}$ and $5^{th}$ graders solved 20 math problems involving two- and three-digit multiplication that were presented to them via software. One group used software that presented the problems, had the student enter their answers and then told the student whether the answer was correct or incorrect. The other software worked the same way, except that after each correct answer, the student was told s/he received 100 points. A running total of points was presented to the student throughout the session and there was also a leaderboard that showed the students who had achieved the highest scores. Results showed that students receiving points scored, on average, 26% higher than those who did not receive points.

  

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The present study investigates whether the mere act of providing points to students for correct answers in math can also raise performance in older students, this time middle and high school students with a testbed of Algebra 1. The topic of mixture problems was chosen since these tend to be challenging for Algebra 1 students. Given that older students are more likely to play videogames than younger students, it is plausible to hypothesize that the effects of awarding points would be even stronger in the present study than it was in the previous one.

## Method

### Participants

Participants were 28 middle and high school students. All had taken Algebra 1. Participants were not paid for their participation.

### Description of Software

There are two versions of the software. One copy awards points to Participants who give correct answers and shows cumulative point totals and one copy just tells the Participant whether his or her answer is right or wrong but does not award points or display overall results. Both versions present Participants with mixture problems, a topic common to Algebra 1 and the SAT test. Because Participants were taught this topic 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 the same 20 problems, expressed in word problem format. The copy with points gives the user 100 points per question, so that the user would be motivated to answer more questions correctly. Users find out that they are awarded points after answering each question. Any awarded points are added to the total points for that session. In the non-points-based copy, at the end of the game, the number of questions that the user got correct is displayed.

### Procedure

Each Participant was tested individually. The Participant was randomly assigned to software version and given a link to the assigned software, which was stored on GitHub. in a one-day session. A total of 13 Participants were assigned to the software with points condition and 15 Participants were assigned to the software with no points condition. Participants were presented with problems one at a time and had as much time as they wanted to solve the problems. After each problem, they were given feedback as to whether they answered the question correctly, and if appropriate, were awarded points for a correct answer. At the end of the session, Participants could see the total number of points they earned or the total number of questions they got right, depending on which condition they were in.

  

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## Results

The Participants were graded on an all-or-none basis. The maximum score was 20 correct answers. As seen in Table 1, the average score for the Participants using the points-based copy of the software was 16.3. For the Participants using the non-points-based copy of the software, the average score was 11.1 (these means were not that different from those in the original Somayyajula, Gajula and Leddo, 2019 study, in which the average score out of 20 with points was 14.5 and without points was 11.5). This difference of nearly 47% was was statistically significant $t= 3.18$, $df =26$, $p < .005$.

**Table 1: Mean Number of Correct Answers Based on Condition**

| Software with Points | Software without Points |
|---|---|
| 16.3 | 11.1 |

## Discussion

The results confirmed the hypothesis that a points-based system could help Participants perform better on mathematics problem solving. The Participants were awarded 100 points for every question they answered correctly, which may have motivated them to earn more points, thereby leading them to perform better on the problems themselves. These findings replicate those of the original Somayyajula, Gajula and Leddo (2019) that shows that awarding points for correct answers improved mathematical problem-solving performance in $4^{th}$ and $5^{th}$ graders, thus suggesting that awarding videogame-style points for performance may be robust and generalizable across age groups. 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 Algebra 1, since they were taught beforehand systems of equations and mixture problems. Previously, we have published papers exploring the effects of different variables on self-directed learning such as student age, aptitude and difficulty of the

  

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material being learned(Leddo et al., 2017; Leddo, Jafri and Jafri, 2022; Nittala, Leddo and Nittala, 2022; Leddo and Kalwala, 2023). It would be interesting to apply the points-based system and leader board to self-directed learning to see if such feedback improves learning there as well. There is reason to question whether results may be different. In the present and Somayyajula, Gajula and Leddo (2019) studies, Participants were tested on subjects they were taught by teachers and on which they knew they would be tested in school. In the self-directed learning paradigm, students often learn subjects for which they have intrinsic interest. In such cases, awarding points for performance may have no additional motivational benefit and not improve performance. Indeed, according to the over justification effect (Lepper, Greene and Nisbett, 1973), rewarding people for performing intrinsically-interesting behaviors can actually reduce performance. In such cases, rewarding students with points when engaged in self-directed learning may backfire.

**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, which may have made solving the problems more interesting to the students.

A second area of research is using AI as an educational tool can be applied to educational videogames 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 with a more interactive learning experience.

  

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