

# Algebra Learning Improved with a COTS Computer Game

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**Abstract.** Computer games have become a part of living in the 21<sup>st</sup> century. Parents and teachers purchase educational video games hoping they will deliver what is stated on the boxes. Few commercially available video games have been scientifically evaluated. This paper presents video game effectiveness studies that have been performed on *Math Blaster Algebra* at John Jay Science and Engineering Academy in San Antonio, Texas. These studies show a positive and statistically significant result of a difference of 7 points out of 100 in favor of the group of students playing the game compared to the control group in test scores. During a five week study period, no negative impacts on any grades or scores were observed, regardless of how much time the game was played by the students.

## 1. INTRODUCTION

There are over 10,000 electronic games available for people to purchase (IGN Entertainment, 2008). There are well over 1000 video games on the market that claim to be educational or have been used for educational purposes (Gaither, Redfield 2009). The games cataloged at [www.wingz2fly.com/GameSurvey/search.html](http://www.wingz2fly.com/GameSurvey/search.html) are educational computer games for personal computers and game consoles, such as Nintendo, Playstation, and Xbox. The games listed at this website are commercially available for purchase by an individual or an organization to use and have some educational purpose associated with them or have been used in an educational setting. Most of these games are made for personal computers. These commercial off-the-shelf (COTS) electronic games include such titles as the

*Blaster* series

by Davidson/Knowledge Adventure,

*Reader Rabbit* series

by The Learning Company /Riverdeep,

*Thinkin' Science Zap*

by Edmark/Riverdeep, and

*Where in the World is Carmen Sandiego*

by Broaderbund/TLC/Riverdeep.

In 2000, it was shown that there were computer software programs to purchase, many of them games, which cover some concepts in all the top-level curriculum topics taught by most public schools in the United States (Redfield, 2000). There is usually at least one computer video game for every major curriculum area from elementary through secondary education including art, business, geography, history, language, mathematics, and the sciences.

Although there is an educational purpose in the development of or usage of these games, there have been very few long-term, scientific, independent, and publicly available effectiveness studies. Christensen and Gerber (1990) did a study with 60 students using *Math*

*Blaster* for elementary-level students that showed the game format was more effective for student learning differences (also referred to as learning-disabled). Wiebe and Martin (1994) used *Where in the World is Carmen Sandiego* with 109 students in only one lab session that showed no significant effects on learning. Doyle and Brown (2000) had 30 students playing *Industry Giant II* over a six week period that showed a positive learning experience. Ncube (2007) performed a study with *Lemonade Tycoon* that said the game had a positive impact on learning manufacturing concepts. There has even been a study in Germany that showed playing the Nintendo Wii Sports: Bowling game improved actual bowling performance for novice and experienced bowlers (Dörrfuß, 2008).

89 different instructional video game studies were summarized in Ke (2009), although most studies are about games that were not available to purchase. Many of the games were made specifically for the studies; and the studies were typically over a short period of time, such as a few hours in one or two days. Some companies have most likely done internal effectiveness studies, such as The Learning Company with the Reader Rabbit titles, but the studies have not been published. There are many other publications that give anecdotal reports of positive results and opinions of students and teachers. A study reported in National Geographic News reports that people who play action-type video games, educational or not, can process visual information quicker, tend to be more attune to surroundings, and track 30% more objects than non-video game players (Roach, 2003). Much research on educational computer games can be found in the *Handbook of Research on Effective Electronic Gaming in Education* (Ferdig, 2009).

This paper reports on the combined results of two five-week effectiveness studies with a total of 85 students at

a high school in San Antonio, Texas<sup>1</sup>. The first study is detailed in a chapter in the Ferdig book (Redfield, Gaither, Redfield, 2009), and it showed a significant difference between control and treatment groups ( $p=.02$ ). The results from the two years of data combined show an even more significant and positive result for learning and understanding from using a game ( $p=.004$ ). The authors had attempted to organize other studies that did not materialize for many reasons including administrator turnover, teachers leaving, reduced access to computers, and changes in curriculum. One potential study was started at a charter school, but did not complete. Doing studies with human subjects, and enough of them to be statistically significant, takes concerted effort and organizational support.

## 2. MATH BLASTER ALGEBRA STUDIES

In order to perform the effectiveness studies, the content area, school, and educational computer game had to be selected. Various curriculum areas and many games were considered in the game selection process. Algebra 1 was selected for the content area for the following reasons given. Testing for understanding math concepts is more straightforward than many other subjects, and there are clearly defined objectives and curriculum for math. Math teachers and professors were available to help make the pre- and post-test and evaluate the math-related computer games. Algebra is a required class in high school curriculums. There were a fair number of educational video games related to algebra. There were 12 at the time of evaluation. Math is fundamental to all the sciences and to logical reasoning, so a substantial benefit can result from an improved understanding of mathematics. Furthermore, everyone can use more math.

The school and students were selected based on the cooperation of the administration and teachers, and availability to the researchers. The teachers were very interested in anything that might help their students. Students could volunteer to be in a control group or a game group. Since one of the researchers attended the school, he could go to the classes to support the students who participated in the study by reminding them to play the game and report the times that they played the game.

The *Math Blaster Algebra* computer game was chosen for the studies for many reasons. It worked on many versions of the Windows operating system; many copies were available to purchase (at least 30 were needed); the cost was reasonable; and the evaluators decided it had the best interface and interaction for high school ages. The *Math Blaster Algebra* game provides an animated adventure on a spaceship called Nomial. Nomial has suffered an asteroid collision. A player must repair the ship operations by solving algebraic problems and gathering resources before the Quadraticas aliens find

them. There are six rooms (communications, defender, electrical, engine, strategy and transporter) and a control center. Each room contains a major activity, and each activity has three levels of difficulty. Scully is a robotic assistant who provides context-sensitive help throughout the voyage including tutorials about algebraic concepts. The image below is a screen from the game showing the Control Center with Scully.



**Figure 1:** Math Blaster Algebra Control Center

A test was developed to compare results for before and after the time period for playing the game. The test needed to be finished in less than a 50 minute class period. Since the game includes all of the topics in Algebra 1, the test was made to cover the major Algebra 1 concepts. Knowledge Share (1998) states that the skills and topics the game includes are

- using decimals, integers and rational numbers,
- understanding algebraic expressions and equations,
- working with ratio, proportion and percent,
- plotting points on a graph,
- factoring polynomials,
- applying the order of operations,
- exploring inequalities and quadratic equations, and
- building and solving equations.

The test used for the pre- and post-test had questions on all of the following topics:

- evaluating expressions including percents and roots
- properties of operations and functions
- characteristics of linear equations and systems
- translations
- solving equations for values and variables
- solving quadratic equations
- simplifying expressions
- inequalities
- graphing
- factors of and factoring polynomials

The test had 25 multiple choice questions. It was scored by awarding 4 points for a correct answer and deducting 1 point for an incorrect answer. The maximum score a student could get was 100 while the minimum was -25. This penalty for guessing was implemented to prevent artificial inflation of scores from guessing. The content of the test and selection of the game was also based on

<sup>1</sup> John Jay Science and Engineering Academy administration and teachers, Ms Greff, Mr Sumpter, Mr Sculley and Ms Gonzales, generously allowed access to students for these projects that also did very well at many science fairs.

the standard curriculum in the Texas Essential Knowledge and Skills (TEKS) by the Texas Education Agency (2007).

Students were recruited to participate on a voluntary basis from multiple class periods. About half of the invited students opted to be a part of the study. Students who participated in the study were either in the game group or the control group. The game group consisted of the students who spent their own time, typically at home, playing *Math Blaster Algebra*. The control group consisted of students who were in the same algebra classes but did not have access to the game. All recruiting followed the school's institutional review board (IRB) approvals, and all subjects and parents of the subjects completed an informed consent form. The students in the game group had to have access to use a computer that could run *Math Blaster Algebra*.

After the informed consent forms were received, the pre-test was given to all the students participating in the studies. The game was distributed by CD-Rom to the game group students, and they were instructed to begin playing. They were asked to play the game for approximately 2 hours a week. The students recorded their playing times and turned in their times at the end of the 5 week period. The students were supported periodically with reminders from the teacher and one of the authors. Students were also motivated by being given points toward a graduation requirement of SEA. After the five week period, a post-test was given to all the students in the study. The post-test had the same questions as the pre-test.

These procedures were repeated two years in a row, during the 2006-7 and 2007-8 academic school years. Both studies were under the same conditions. The students were in the same grade (9<sup>th</sup> grade) and class (Algebra I), in the same school (John Jay Science and Engineering Academy), had the same math teacher (Ms Gonzales), had the same incentives (points toward a school requirement and/or extra credit), the same text book, the same curriculum (both studies were performed during the same second quarter of the school year), and even the same physical classroom. The environment and situation similarities easily allowed for the data from both years to be combined and analyzed together as discussed in the next section.

### 3. COMBINED RESULTS

The following table shows summary data on the scores for the pre-test, post-test, and difference between the two tests for each student. The maximum score is 100. There were a total of 42 students in the game group and 43 students in the control group for the two studies combined. Over the 5 weeks, the game group students played an average of 11.5 hours each, or a little more than 2 hours a week. One student played 58 hours during the 5 weeks.

**Table 1:** Pre- and Post-test scores and difference

Test Scores out of 100 Points		MIN (minimum)	MAX (maximum)	AVG (average)
Game Group (n=42)	Pre-test	-3	39	16.9
	Post-test (5 weeks)	-2	55	20.4
	Difference (post-pre)	-29	24	<b>+3.5</b>
Control Group (n=43)	Pre-test	-8	79	24.2
	Post-test (5 weeks)	-7	60	20.6
	Difference (post-pre)	-50	24	<b>-3.6</b>

The control group scored better than the game group by 6.3 points out of 100 on the pre-test. At the 5-week-test, the two groups scored closer together (a difference of 0.2%), with the control group's scores falling and the game group's scores rising. The game group's average score rose 3.5 points, while the control group's average score fell by 3.6 points. These changes were significantly different ( $P = .009$  one-tailed) and indicate an overall increase of 7.1% for the game group, which is most likely due to playing *Math Blaster Algebra*.

There were large variances in the scores for both tests. The game group scores had a range of 40 points on the pre-test and the control group scores ranged over 80 points. Students' capabilities seemed to range widely. Results from the pre-test seemed to show that students from the control group began the study with a greater level of understanding and performance of algebraic concepts than the game group. The significant difference for the post-test suggests an affect by the game in the five weeks they had to play it, although there was no difference in a 15-week-test that was given to the second group of students in trying to extend the length of the study.

Regarding students' grade averages, no significant changes were noted between any of the marking periods. While playing the game did not increase their grade averages, spending time on the game did not have a negative impact on their grades or other scores for school. If nothing else, *Math Blaster Algebra* encouraged the students to spend more time working with Algebra 1 concepts without hurting their grades. It is also important to note that since grade averages are affected by many factors other than just student understanding, it is not necessarily an accurate measure of the game's effectiveness.

The game group students who reported their hours played *Math Blaster Algebra* for a total of 448 hours within the two 5-week studies. In the second year, the study continued for another 10 weeks beyond the first 5 week period. However, with this extended study period, the game group in this second year of the study played *Math Blaster Algebra* for only 10 hours more than the students played in the 5 weeks for the first year. There seemed to be a loss of interest in the game over time and may imply that the 5-6 week time period is a good length of time to use a game for supplemental instructional support. No additional significant differences appeared in the data for the longer study. It is interesting to note that, as in the first study, no negative effect was seen in the scores and grades, no matter how much students played the game. All totaled for both years and with the extended study, the game group students played 562 hours of *Math Blaster Algebra* over the 42 students. Therefore, they spent that much more time doing the task of learning and practicing algebra than they would have otherwise.

#### 4. CONCLUSION AND FUTURE WORK

Overall, it was shown that educational games can be effective over a period of time similar to a 6-week marking period, but it is important to remember that this study is only a single evaluation on one educational game. Hopefully, more studies on the effects of educational gaming will be performed, and a more comprehensive determination of the possibilities of these games will be developed. Some studies could be developed to consider the effectiveness during different times of a school year and during long academic breaks to see if retention can be improved. Some studies could include a more controlled use of a game in a classroom. A study is currently in its second year of work by the authors about supporting retention of algebra skills and concepts over a summer break. The preliminary results look promising.

As with any activity, video game playing should be done in moderation and not interfere with other goals and plans for family, school, and work. Educational video games can be used to help motivate students to spend time with a task. It is alright to allow, even encourage, students to play video games, especially educational ones. Keep studying; keep playing; game on!

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