Gaming the Classroom: Results from a Pilot in Changing the Teaching Paradigm for Algebra Instruction

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Math achievement among US high school students is low; a 15-year-old US students' average mathematics literacy score places them in the bottom quarter of students worldwide (NCES, 2010). According to Loveless' (2009) review of NAEP data, gains in math for both low- and high-achieving U.S. high school students are also low, suggesting limited, if any, improvement in recent years. As the global economy becomes more technology-based, a thorough understanding of advanced math courses is necessary to function and thrive in a world that is increasingly interconnected. Despite calls by researchers to reform the way the US educates students in math, few students are completing higher-level math courses; deciding, instead, to strive for minimal math standards, at best. Ethnic minority students are particularly underrepresented in the most rigorous math classes, with low motivation cited as a dominant reason (Riegle-Crumb, 2006, Ruiz, 2011). Lack of student interest in mathematics coupled with low math achievement may be detrimental to the US maintaining its stature in the world community and contribute to the domestic decline of teenagers choosing STEM careers. The purpose of this mixed methods study was to investigate teacher and student perceptions of adapting video game design principles for algebra instruction for struggling students in an attempt to increase student engagement and achievement.

Background

Algebra is widely considered as a gatekeeper to higher education (Johnson, 2010; U.S. Department of Education, 2008). Typically taken in 9th or 10th grade, the earlier students successfully complete algebra, the greater the probability they will engage in more challenging math curricula at later points along the educational pipeline (US Department of Education, 2008). Algebra differs from typical elementary mathematics courses; it moves from concrete arithmetic functions to more abstract and logical thinking, which represents a dramatic shift in thinking. Students display readiness for this type of formal operational processing at different times in their development.

Some students develop at a faster rate and are ready to engage in abstract/logical thinking at a much younger age have minimal access to opportunities to move forward in their development through an appropriately challenging curriculum. These students may display a lack of motivation and frustration and disengage from mathematics curriculum if they are forced to remain with their age-mates covering material that they have already mastered.

Anxiety

Students who struggle with the ways algebraic problems are reasoned through may require more scaffolding than other students and, thus, may display a lack of motivation and persistence on difficult tasks (Riegle-Crumb, 2006). If students experience math anxiety as a result of lower performance than their peers, they may avoid math as a coping mechanism to deal with their anxiety (Ashcraft & Krause, 2007). While this behavior may provide short-term relief, it creates negative results by limiting individual opportunities to engage in higher mathematics coursework but also practically speaking my limit the likelihood of having higher level math courses accessible to higher ability student in the local school communities.

Additionally, Ashcraft and Krause (2007) found that the correlation between math anxiety and mathematics performance was -0.35 for overall tasks. Interestingly, they found that as the mathematics tasks increased in difficulty the influence of math anxiety became more pronounced with decreased performance. The authors found that as math tasks increased in complexity more demands were made on students' working memory. If the working memory resources were already limited due to highly anxious students focusing on their own feelings then performance would diminish (Ashcraft & Krause, 2007). Thus math anxiety may become more pronounced and its interference more noticeable as students progress from arithmetic to more abstract mathematics such as algebra.

Significant factors in math anxiety are teacher behaviors and classroom environment. Geist (2010) found that teachers who stressed timed-tests, high stakes testing and focused on correctness increased anxiety levels for students. Conversely teachers who focused on conceptual understanding and interactive approaches reduced math anxiety in students (Geist, 2010). He also found that the majority of mathematics education is taught without regard to differences in student readiness or learning preferences. This generic approach to teaching may disadvantage female students and those who need instruction at a faster or slower than average pace (Geist, 2010).

Motivation

It is necessary to understand the components of motivation associated with the activities that students pursue outside of school to understand what can be interpreted as a lack of motivation to learn math in traditional didactic ways. Video games offer an opportunity for such an examination. The video game industry is thriving even when most other aspects of the economy are struggling. Recent reports by the Entertainment Software Association show that the video game industry enjoyed sales of over $25 billion last year (2011). Approximately 72% of households play video games on a regular basis (Entertainment Software Association, 2011); thus, most students are familiar with this approach of relating to and engaging in puzzle or problem-solving activities with new or familiar content. Video game players receive no external recognition for their in-game accomplishments and are quite willing to pay significant amounts of money to purchase and play the games; moreover, video game players spend innumerable hours invested in game play. All of these factors shed light on the degree of motivation individuals have to play video games. As such, it makes sense to research the possibility of successfully operationalizing the approaches that are motivating to gamers in formal educational settings.

While acknowledging that video games are played for “fun,” little research has explored the exact components of the games that motivate players to become so engaged in the act of gaming. Several researchers have identified game characteristics that contribute to being described as “fun” (Huizenga, J., Admiraal, W., Akkerman, S., & ten Dam, G., 2009; Malone, 1981; Squire, 2006). With new games created daily and bargain bins of unsuccessful games in many stores, trying to specify game characteristics associated with the construct is extremely difficult. This method of quantifying “fun” also dismisses individual differences in reasons for playing games; therefore, a more individualistic empirical understanding is needed.

Yee (2006) and Ryan, Rigby, and Przybylski (2006) applied quantitative methods to examine models of motivation and their relationships to video game engagement and persistence. Their models of persistence and motivation have important implications for students pursuing challenging STEM courses. Yee, was the first to apply statistical analysis to video game playing, he found three components that drive motivation for continued play: (a) achievement – the ability to advance and feeling of competition between the player and the game; (b) socialization – building relationships among other players including in-game chatting and helping, as well as teamwork, and (c) immersion – the game storyline, level of discovery within the game, and the ability to customize the game character (2006). Building on the empirical analysis of Yee, Ryan

and colleagues used the Self-Determination Theory of Motivation to examine player motivation in four studies (2006). According to their findings, player perceptions of autonomy, competence, and relatedness explain a significant portion of the predicted game play variance and are better predictors of continued game play than Yee's components. Both studies demonstrate the value of examining video games using quantitative analyses and a motivational framework.
Understanding motivational components for activities that students seek outside of school will provide insight into creating STEM instructional design models that enhance student motivation for challenging courses.

Design of Instruction

Theories of motivation provide insight into what makes video games "fun," but no research has studied the effects of using these motivational models in educational interventions designed to increase student engagement and motivation. It is not enough for teachers to add activities that they believe students will perceive as "fun". Teachers must experience a paradigm shift in instructional design pedagogy. Specifically, the components that have been found to significantly predict student engagement and persistence in video games should be used to adapt instructional methods.

While persistence and intrinsic motivation have been observed in people who play video games, research regarding the specific characteristics and variables that foster these behaviors within the games is sparse. Teachers and researchers are increasingly pursuing opportunities to use game-like interfaces to improve student learning; however, without an evidenced-based understanding of gaming and it relationship to learning instructional designers risk designing instruction that does not improve learning. This lack of understanding how to align motivation, gaming, design, and learning can continue to exacerbate low student achievement, waste tremendous amounts of time, money and resources.

Berliner and Biddle (1995) noted that how students are motivated determines the degree to which they are able to grasp material. This study was designed to explore the motivational variables associated with gaming and how teachers may best incorporate these variables into algebra curriculum as a means to increase students' motivation and engagement with the material. Research related to specific motivational gaming components associated with teaching algebra has not been conducted.

Although the focus of this study is on math instruction, pedagogical methods created by the instructional model can be adapted for a myriad of subject areas. Understanding how to integrate technology and motivational characteristics into classroom teaching provides an opportunity for teachers and researchers to understand how to capitalize on the "fun" aspect of gaming and harness this power for learning. The purpose of this study was to investigate the dynamics of motivation that are evident in video games and how they can be translated into classroom learning with a pilot group of students.

Hypotheses

This study is an investigation of the impact of video game design model on high school algebra students' mathematics achievement and motivation. The study has three objectives: (1) create modules that will enable teachers to utilize video game motivational components in their classroom; (2) explore teacher implementation and student response to the paradigm shift in algebra instruction; (3) use mixed-methods research to establish evidence regarding the effectiveness of using video game motivational components in instruction. Specifically, we hypothesize that an educational intervention combining the motivational aspects of gaming with algebra curriculum and lesson plans will result in the following outcomes:

Hypothesis 1: Student engagement and persistence in working with algebraic content will increase.

Hypothesis 2: Students' perceived in-game autonomy, competence, and relatedness will be positively related to levels of engagement, persistence, and lower math anxiety.

Hypothesis 3: Increased engagement, persistence, and lower math anxiety will improve students' achievement levels in algebra.

To clarify, although various video games were used in this study, it is the implementation of video game design principals in the design of instruction that were investigated. Specifically we focused on autonomy and choice in the lessons, timing, and assignments in designing the instruction.

Methodology and Data Sources

This study used mixed methods research techniques. The qualitative component consisted of observation, interview, and surveys. The quantitative component compared student performance on the chapter exam to prior chapters and to previous years' class performance on the chapter. It was important to use qualitative techniques to obtain a deep understanding of the teacher and student reactions to the instructional shift in the classroom.

Participants

The participants of this pilot study were 15 students and an algebra teacher in a private, parochial school in the Mid-west. They were enrolled in a remedial algebra class that met daily for 50 minutes each day. The majority of the participants (13) were in 9^{th} grade, one student was in 8^{th} grade and one student was in 10^{th} grade. Twelve of the students were Caucasian, two were African American and one was Indian. There were six females and nine males in the class. This class was new in the course offerings at the school. In past, all of the algebra classes had students of mixed ability. The administration decided to divide the students based on their prior math performance to provide extra assistance to struggling students. These students were purposefully chosen for this study because they struggled in mathematics and did not seem to be engaged in the classroom activities. Notably, the classroom teacher had remarked that when preparing for an upcoming exam some of the students could not even identify the chapter that they should be studying. The teacher was open and excited to try new teaching methods to enhance student engagement.

Setting

The researcher and pilot teacher collaborated to create a game-like environment for students to learn the mathematical concepts of graphing linear equations. The environment used the components of choice and autonomy that had been detailed in the literature as important aspects of video game enjoyment. As such, for each section of the textbook chapter, students were given several options in regards to methods of receiving instruction and means by which they could practice the newly acquired understanding. Students were always given the option to follow the traditional path of reading and working through their textbook chapters. In addition, they were provided with instructional videos, interactive videos, games, and printed worksheets that could be completed alone or with a partner. These instructional materials and activities were labeled as quests and students were awarded experience points for completion of each quest.

In an effort to enhance the game atmosphere, the researcher and teacher utilized a computerized learning platform that allowed students to create avatars and track their progress electronically (3D Gamelab Software Platform, 2012). The researcher and teacher could also provide electronic rewards to the students via the use of the platform in the form of badges that would be attached to the avatar. The new learning experience was referred to as 3D Gamelab in the classroom. As students accumulated varying amounts of experience points they increased in level and unlocked new opportunities for experience and thus moved forward in the chapter. The students were also informed that the student who obtained the overall highest number of experience points would be excused from taking the final exam.

Data Sources

qualitative data. Extended observations lasting over 25 hours, teacher interviews (12) and student focus group interviews provided ongoing evaluation of the intervention.

The observations consisted of noting the number of students who were on task, how quickly the students began working on the program, the progress that students made in the program, and student interactions with one another regarding the new program. Focus groups occurred prior to instruction and consisted of the researcher asking small groups of students to describe what they liked or did not like about the new instruction format and soliciting suggestions for improvement. Both the researcher and the teacher would question students to check their understanding of the content and also gauge the student interest in the new format. An open-ended exit survey was administered to gather more detailed information on student perception of the gaming format. This survey asked students to tell what they liked about the game format, how engaged they were during the process, how they felt the game format compared to other teaching methods, and any challenges or difficulties that they encountered in the game.

quantitative data. Surveys administered at the beginning of the intervention provided information regarding the student experience. The survey used Likert responses to quantify initial student perceptions of the gaming environment. Questions on the initial student survey were "*Which quests are you finding that you like completing the most? What are your general feelings of using 3D Game Lab after one week? How do you feel about the instruction that you are getting for the sections?*" They were able to choose their response from drop down menus to standardized the responses. Students were also asked the open-ended question of "*What have been some of the confusing parts of using the game?*" Prior performance on chapter tests, student performance on weekly quizzes and the final chapter test provided the quantitative component to measure student achievement. Prior mixed-ability class results on this chapter examination were also investigated as a comparison of the difficulty of the material.

Results

Results of this pilot study were mixed. Student reports and researcher observations varied considerably especially as the study progressed. Strengths of the new pedagogical format were evident in student engagement and reports of enjoyment. However, weaknesses in the design of the new format implementation and understanding of the scaffolding requirements of the teacher and students were also revealed.

In response to hypothesis one, teacher and researcher observation were quite different than students' perceptions. Teacher reports and classroom observations found the students to be much more engaged with the material than they had been with traditional instruction. The classroom teacher had reported that during the 50 minute class period he could only sustain 15 minutes of instruction with the students (3/27/12). Classroom observations showed that the majority of the students were engaged throughout the entire period. However, when asked about their level of engagement on the final survey, five out of twelve students indicated that they were less engaged and four out of twelve indicated that their engagement remained the same. Only three students reported being more engaged with the new learning format. One student commented that the games and being on the computer actually made it easier to get off task. Initial observation and teacher reports indicated that students were much more engaged with the game format of the classroom. These concurrent early observations from the teacher and researcher during the experience compared to the final levels reported in the engagement survey by the students would seem to indicate that engagement of the novel approach to learning math was not overall more engaging for the students.

Students came in and immediately began working with the computer program. However, two weeks into the study reports by the students via the initial survey and focus groups interviews gave feedback that the students were frustrated with the requirement of creating their own understanding from the material provided. When asked "what do you like and dislike about the new format?" students noted that they missed face-to-face instruction. They did not like getting instruction through watching videos (Focus Group Interview 4/16/12, 4/17/12). These students were used to having the teacher break down the instruction into daily manageable bits and provide them with notes and lectures. Suddenly the students were thrust into a situation where they were responsible for taking the information and deciding what was important. The teacher felt that this experience was good for the students even though they were struggling. "I think a big problem is that these kids aren't used to being independent learners. They are used to everything being given to them. This is different. This is a challenge but I think it is good for them. They need this" (Interview 4/3/12).

However, students reported positive aspects of the new format being the freedom to choose the instruction methods and assignments and moving at their own pace. "I like it because you can do it on your own time and pick your own games" (Focus Group 4/16/12). The majority of the students expressed positive thoughts regarding the math video games that were included in each section "I like the games. They tell you if you're working right and once you're wrong a few times you get it and it helps" (Focus Group 4/16/12).

Findings relating to hypothesis two that student perceptions of autonomy and competence would result in increased persistence and engagement and lower math anxiety were mixed. The theme of autonomy permeated student responses to open-ended survey questions. The ability to choose the assignment and the pace of instruction was seen as a benefit by some students and the most challenging aspect by others. As struggling students, most of their classroom experiences have been very teacher-centered with instruction given in small, specific steps. The piloted instructional shift in pedagogical approach to classroom instruction was significantly different from the traditional experiences of these students. Thus two themes emerged from the student data. The first was that students noticed and responded to increased autonomy and choice in their math instruction. The second theme was a need for support and scaffolding in transitioning to the new learning practices.

The exit survey asked students to respond to the question "*Please tell us what you liked about 3D Gamelab?*" As expected, most students indicated that they enjoyed playing the games that were included with each section. It was interesting to note that over half of the students indicated they liked aspects of autonomy. "I liked that it was our responsibility to earn the XP [experience points] not the teacher's" (Survey 9-1) "It's on your hands to teach it right or understand" (Survey 6-1). "We got to choose what homework assignment we wanted to do and you get to turn it in when you want" (13-1). "I liked working on my own time" (7-1).

Students also commented on aspects of autonomy (independent learning) as the most challenging aspect of the new format. When asked "*What was challenging or difficult about learning in the 3D Gamelab*?" students frequently cited having to create the understanding on their own as quite challenging. "No one was telling us what to do" (11-2). "It was hard learning how to do it. You had to study with the book" (9-2). "It was challenging not having a teacher there 24/7. I learned how to teach myself more"(12-2). Thus, even when small group instruction was implemented and both the teacher and researcher were available to answer questions as the students were working, the students reported feeling that they were learning alone or left on their own to learn the material.

Student perceptions of competence were difficult to gauge. The exit survey indicated that most students struggled with self-directed learning. The students' mean scores on the three quizzes given over the chapter were 70%, 85%, and 70%. This feedback in addition to progressing through the experience point quests should have supported student feelings of competence; however, that was not reflected in the exit survey. Some students reported that this chapter seemed much harder than previous chapters and that they felt confused when trying to "I felt like it [the new gaming format] was harder than other chapters because we didn't really have someone telling us what to do" (11-1).

The theme of a need for scaffolding emerged on the first day of observations. Numerous students required assistance on creating their avatars and sending screen shots to the teacher (Observation 3/27/12). Later in the week numerous students commented feeling confused regarding due dates for quests (assignments) and understanding instructions (survey 4/2/2012). Although a great deal of attention was paid to creating the quest content learning opportunities, students and the teacher demonstrated a need for activities to ease their adjustment to the new instructional format prior to working with the content.

The teacher reported feeling overwhelmed by the amount of administrative effort that was required to acclimate the students to the new format and to respond to student work (Teacher Interview 4/2/12). Prior to this study, the teacher employed traditional math teaching techniques of face-to-face instruction where the teacher would lecture and provide examples then assign homework practice problems. The teacher's worked examples came directly from the textbook thus negating the need for students to use the book other than for homework. The instructional design allowed students to learn at their own pace by utilizing instructional videos, webpages, and textbook readings. Some students expressed feelings of frustration regarding how to learn using the game platform. "I don't like it [the new format] because you don't have a teacher in front of you explaining what to do. You have to do it on your own" (Focus Group Interview 4/16/12). "I am missing the face-to-face teaching. This [the new format] makes it hard to learn. I can raise my had to ask questions but I don't have anyone face-to-face teaching me" (Focus Group Interview 4/17/12). Although both the teacher and the researcher circulated through the students to assist in explanations and answer questions the students seemed unclear of their ability to identify key information. This confusion was evident on the first quiz scores (M = 70%). Student feedback and poor performance on the first quiz made the need for modifications to the new instruction design. It was apparent that the most students required scaffolding in both understanding the concepts and creating a schedule for moving through the program. Thus, the teacher and researcher began dividing the class daily and providing small group instruction to 7-8 students on alternating days. The remaining students worked using the game design on their non-instruction days. Small group instruction seemed to ease the frustration of the students who did not understand the instructional videos. The teacher also provided chapter outlines for students to use as they worked on the assignments and instruction to emphasize the key concepts of the unit.

The results of hypothesis three were also mixed. The hypothesis was that increased levels of engagement and persistence would result in increased academic performance. The mean of the chapter final exam was 67% with a standard deviation of 12%. The median score was 71%. Prior chapter final exam results for this class were 71% and 72%. In previous years when this chapter was taught in mixed-ability classes the final exam results were 79%. This chapter focused on graphical equations of lines and translating algebraic expressions into graphs. Both the teacher and researcher noted that historically students generally struggle with these concepts regardless of mathematical ability.

Discussion

As a pilot study, this research was successful in that it gave insight into student needs regarding scaffolding for functioning in an independent learning environment. It also provided information regarding teacher training needs and scaffolding requirements to implement the new curricular format.

The motivational aspects of autonomy, competence, and relatedness noted by Ryan et al (2006) were apparent in the study. Students noticed and commented on the freedom of choice in assignments, instruction, and pace. However, some students were overwhelmed by the new found freedom and expressed a need for more teacher-directed learning. Lack of appropriate scaffolding and support also left the teacher and students feeling confused which may have influenced their perceived levels of competence in working in the new format. Student performance on the first quiz reflected the lack of competence and confusion in identifying key concepts in the instruction. The addition of small group instruction and more online support to clarify assignments led to improved performance on the subsequent quiz. The design of instruction relied on the teacher to support the role-playing aspect of the pedagogical shift to enhance feelings of relatedness among the students. The teacher only superficially embraced the role-playing feature by referring to quizzes as “monster attacks” and allowing students to choose the monster that they would face. Thus opportunities to enhance feelings of relatedness were diminished.

Another reason that student perceptions of competence may be reduced is that the concepts taught in this unit are some of the most difficult for beginning algebra students to understand (equations of lines, graphing lines, calculating slopes) and it is common for students to struggle in this unit. The researcher and teacher had previously taught a combined thirteen algebra classes and noted that historically this content area was one in which most student struggle and academic performance declines. Cavanaugh, Gillian, Bosnick, and Hess reported in their study that this component of the algebra curriculum was identified as one of five areas of difficulty for over 1300 students (Cavanaugh et al., 2008). One student in the current study commented that he felt the concepts of this content area were much more difficult than previous chapters and suggested that in the future an easier section may be more successful for independent student learning (8-1).

Information from the exit surveys indicated that most of the students enjoyed being able to pace themselves with the amount of work (6-1, 10-1, 12-1). They also reported enjoying the computer games that were implemented in addition to written exercises. Students suggested being able to see a scoreboard for the class and to actually see their character moving on a board would improve the gaming experience. They also recommended including a wider variety of computer games that allowed them to practice their skills to improve the experience.

Limitations

As previously mentioned, a weakness of this pilot study was the lack of teacher training and scaffolding to implement the change in pedagogical approach. Future studies would benefit from devoting significant attention to developing a training model for the teachers prior to supporting them in working with the students. The teacher did not embrace the game environment and thus a key contribution of the initial concept of “gaming” the classroom became lost. Even though the teacher plays video games and understood the concept of teaching as a game actual implementation in a four-walled classroom proved too big of a challenge. Thus, some of the advantages of the gaming atmosphere (role playing, competition) were minimized.

Using self-report measures relies on student perceptions and honesty in answering questions. Adolescents may be susceptible to responding in socially desirable ways when asked questions regarding their engagement and commenting on their performance. Similarly, the students in this study may have been reluctant to communicate in an honest manner for fear of repercussions with their grade although all had been reassured that their responses would not be shared with the teacher until after the unit was finished.

This sample of students was chosen purposefully in order to provide an intervention to a group that struggled with math and did not appear interested in the content. However, the lack of interest and decreased sense of competence may have adversely affected results of engagement and academic performance that may not been seen in students with average or above-average math ability or interest in mathematics. Similarly, this pilot group was chosen because the small number of students could allow the researcher to observe the student engagement and conduct focus group interviews to obtain feedback on the experience. The small number and unique characteristics of the participants limit the generalizability of any findings beyond the 14 students in the study.

Scholarly Significance

Enabling teachers to view video games in terms of specific components of motivation and development may afford teachers significant insight in how and when students need their ideas scaffold. This has potential impact on how they interact and perceive their overall instructional practice even when not in gaming environments. Teachers may begin to view their classes through the lens of a game and redefine rules for social interactions, rethink objectives that focus on successful conditions or limited success. Additionally gaming introduces components of fantasy or mystery to learning situations that my help ideas to be represented in ways that require scaffolding that a teacher would not have ordinarily thought of or planned. Computers and technology in the classroom can support student autonomy by providing multiple choices in activities that vary in their level of difficulty. This again can foster technology-based scaffolds and digitally-based pathways that could aide in student achievement provided a balance is fostered and maintained in the classroom community. Lastly using a video game model for math instruction may reduce math anxiety by using a new approach to teaching and learning mathematics.

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