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Effects of Game-Based Learning on Attitude and Achievement in Elementary Mathematics

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Effects of Game-Based Learning on Attitude and Achievement in Elementary Mathematics

Abstract

Games-based learning involves instruction with realistic game experiences (Cicchino, 2015). This action research study explored game-based learning as fifth grade mathematics students completed a brief unit on ordered pairs utilizing game-based lessons. Attitude and achievement data were collected mainly by surveys, content tests, student interviews, and field notes. Additional information included in the teacher-researcher analysis consisted of classroom photographs, videos, and student work samples. Results revealed that student attitudes improved both toward the lessons and toward math in general. Similarly, achievement improved for all students across the unit. Analysis of the narrative data produced three themes. First, the students acquired a growth mindset (Boaler, 2016) that fostered a positive work ethic. Second, student partner work helped them to develop problem solving skills. And third, the games engaged the students. In summary, students showed significant improvements both in their attitudes about math and their achievement in ordered pairs.

Many students begin to develop negative attitudes about mathematics during their first few years in the elementary classroom (Leroy & Bressoux, 2016). By the time these students reach the fifth grade many of them inherently struggle at math, simply because they do not learn best through the common process of rote memorization. Rather they would better succeed through a process that is exploratory, collaborative, and challenging (Kebritchi, Hirumi, & Bai, 2010). Leroy and Bressoux (2016) note that when elementary students struggle, these attitudes about mathematics can be toxic to a productive atmosphere, fostering low motivation and drive. Boaler (2016), one of the leading researchers on students' mathematics motivation, believes "the difference between those who succeed and those who don't is not in the brains they were born with, but their approach to life, the messages they receive about their potential, and the opportunities they have to learn" (p. 5).

Researchers assert that most students' dislike for mathematics stems from the way that the subject is presented in the classroom (Boaler, 2014; Dossel, 2016; Hunt, 1985; Reyes, 1984). The current presentation of mathematics in many elementary school classrooms relies on the sequential description of mathematical concepts, followed by repetitive drill and practice to master specific content (Olson, 1999). This rigid structure leads students to view math as a chore that needs to be completed, rather than a puzzle that needs to be figured out.

Many elementary students develop mathematics anxiety, or "a feeling of tension, apprehension, or fear that interferes with math performance" and begin to dread the time of day devoted to the subject (Hunt, 1985, p. 32). Students can develop a fixed mindset about mathematics, believing that they are either inherently successful at it, or they are bad at math (Boaler, 2016). Moving away from these "fixed" practices can not only help change the way that students view mathematics, but also the way that they view themselves.

Findings by Linder, Smart, and Cribbs (2015) suggest successful mathematics instruction is centered on student interests and experiences. Children are naturally inquisitive by nature, interested in the process of solving puzzles and trying to work things out. Guided discovery-learning in the classroom entails the teacher's introduction of a complex problem which the students are able to work together to solve (Janssen, Westbroek, & Van Driel, 2014). This process of social scaffolding, helps the students to "become more motivated, develop flexible knowledge, and learn how knowledge is developed in a specific domain" (Janssen et al., 2014, p. 67). Another classroom activity that promotes student-driven exploration is the use of gaming in the classroom. Serious games, which are defined as games that were created with the purpose of education in mind, help to increase student engagement and motivation (Young et al., 2012). Other researchers (Cicchino, 2015; Habgood & Ainsworth, 2011) have concluded that game-based learning (GBL) can be very effective for the development of student intrinsic motivation and critical thinking in the classroom.

Serious games target the intrinsic motivation of students, relying on their internal drives for competition, interaction, and creativity. According to Vygotsky (1978), children are inherently social beings who learn best through investigation, and interaction with others. GBL is founded on this principle of social interaction, as serious games give students opportunities to explore concepts through the form of competitive exploration. Research has examined the effect of competition on learning. Results from recent studies have found that competition improves motivation and cooperation, and ultimately learning outcomes (Burguillo, 2010; Cagiltay, Ozcelik, & Ozcelik, (2015).

In one study, Kebritchi et al. (2010) examined the effects of incorporating serious GBL into the pre-algebra math classroom. According to the classroom teachers in this study, the use of serious gaming was effective because the games were experiential in nature, offered a new way to present and experience learning, gave the students context and motivation to work on the mathematics concepts at hand, and made math fun.

The purpose of the current action research study was to study the effect of game-based learning for fifth grade mathematics learners. Given the potential positive effects of game-based learning instruction as identified by the related literature, the teacher-researcher determined to implement and examine the use of serious gaming activities in fifth grade mathematics. Specifically, she studied the topic of ordered pairs and the effect of serious gaming activities on student attitude and achievement.

Methodology

This action research study was conducted at a public elementary school in the southeastern United States with a standard-level fifth grade math class. The first author was the teacher-researcher, and this study was an extension of her normal work in the classroom. The class had twenty-seven students, and the study used data from the twenty-four students who returned signed informed consent and assent forms with permission to participate in the study and were present each day. The demographics of the sample included Caucasian, Hispanic, African American, and Asian/Pacific Islander students, and were split evenly among genders with twelve males and twelve females.

The treatment period for this research study spanned the course of five school days. The first and last days of the study were used for pre and post assessments and attitude survey administration. Student interviews were conducted on the final day. Each interview lasted between five and ten minutes and included questions such as, "How do you feel about math in the classroom?" "What have you thought about the game-based learning we have been doing?" and "What has been your favorite/least favorite activity?" These semi-structured interviews were audio recorded and then transcribed.

The middle three days were designated as instructional days to incorporate principles of game-based learning into classroom instruction. The periods of math instruction lasted sixty minutes each. The instructional activities were designed and sequenced by the teacher-researcher, based on the North Carolina Standard Course of Study. Specifically, this series of lessons addressed Standard 5.g.2: Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation (NCDPI, 2017).

During Day 2 (the first day of the game-based learning instruction) students viewed the video, *Coordinate Plane Song: Ordered Pairs Rap for Kids* and clarified the vocabulary that was presented in the video. Next, after brief instruction, the students played *Battleship* to reinforce

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their understanding of ordered pairs. The goal of this lesson was for students to learn vocabulary and skills in graphing points in the first quadrant.

On Day 3, the students were asked to identify at least fifteen points on a coordinate grid and write a creative story using the emojis at those grid points to describe their coordinate path in their Emojilicious Coordinate Story. The goal of this lesson was for students to apply their knowledge of ordered pairs in a creative writing context. See Appendix B.

On the final day of instruction, students rotated through a set of five stations including Dice Game, Mission: Zombies, Connect Four, Finger Twister, and City Planner. Each of the stations asked students to use their knowledge of ordered pairs to think critically and develop a strategy for the particular activity. The goal of this lesson was for students to apply their knowledge of ordered pairs in a problem-solving context.

Data Collection

In order to examine the effect of game-based learning on student attitude and achievement, data were collected from interviews, video recordings, field notes, surveys, and pretest, midtest, and posttest assessments.

Measures of Attitude. Data on student attitude toward mathematics were collected through daily surveys, student interviews, still photographs, and researcher field notes.

Daily Attitude Survey. The daily Attitude Survey was created by the teacher-researcher and contained three questions to gauge student feelings toward the daily lessons and mathematics in general. These followed the guidelines for a basic Likert-scale survey (Gay, Mills & Airasian (2012). These three questions were, (1) Circle the emojis that represent how you feel about today's lesson (feel free to circle more than one), (2) Circle the emojis that represent how you feel about math in general (feel free to circle more than one), and (3) What else would you like to tell me about learning math? For the first two questions, students were provided with emojis that correspond to each of the words: unhappy, worried, bored, surprised, good, happy, and other. For the final question, the students were given two lines to freely express anything else they wished to include in the survey. See Appendix A. This first survey was used as an initial baseline of each individual student's feelings toward everyday math lessons and math lessons in general. The teacher-researcher also gave the students ten minutes to respond to the survey after each day of the action research instruction.

Student Interviews. On the day following the game-based instruction, the researcher pulled out individual students to interview them about their attitude toward game-based learning and mathematics. Seven students were purposefully selected based on their daily interactions in class, responses to the survey, and achievement in ordered pairs. Each interview lasted between five and ten minutes and included questions such as, "How do you feel about math in the classroom?", "What have you thought about the game-based learning we have been doing?", and "What has been your favorite/least favorite activity?" These semi-structured interviews were audio recorded and then transcribed. Finally, the teacher-researcher used open, axial, and selective coding methods to select major themes on student attitude from all of the interviews.

Still Photographs and Researcher Field Notes. Each day, as the students were completing the assigned activity, the teacher-researcher circled the room and took photographs of the students. Following instruction, the teacher-researcher reviewed the various photographs and compared them to her field notes for that day. She looked specifically for details and trends that would help her to further understand student attitude toward the lesson, and mathematics in general. These details include, but are not limited to, the facial expression of students, body language of students, and number of students actively participating in the activity.

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Measures of Achievement. Data on student achievement in ordered pairs were collected through student assessment, student artifacts, video recordings, and researcher field notes.

Student Assessment. Student assessment data were collected through a unit-specific pretest, midtest, and posttest. The pretest was administered by the teacher-researcher at the start of the class on the first day of instruction. Based on the state standards, the pretest contained ten questions. The first five questions asked students to name an ordered pair from a point on a graph, while the final five asked students to plot a point on a graph using only the name of the ordered pair. Students were given ten minutes to complete the assessment.

The midtest occurred on day two of instruction and was comprised of a cross-curricular game-based activity that asked students to identify at least fifteen points on a coordinate grid and write a creative story using the emojis at those grid points to describe their coordinate path. The researcher allowed students forty minutes to complete the entire activity. These Emojilicious Coordinate Worksheets were then graded on the accuracy of the placement of student coordinate points and the corresponding details that the students described in their coordinate stories. Twenty-three students with permission to participate in the research were in class and able to complete the midtest activity. A class average was computed from all of the students' scores.

The posttest was administered by the teacher-researcher on the day following completion of the unit. The posttest was identical to the pretest that was given to the students at the start of the unit. This consistency in the two assessments allowed the researcher to determine how much growth each student made throughout the unit. Students were given ten minutes to complete the assessment. Twenty-four students with permission to participate in the research were in class and able to take the assessment. A class average for the posttest was computed and compared with the scores on the pretest and midtest.

Student Artifacts. Student work from all daily activities was collected at the completion of the class period. These artifacts include, but are not limited to, the Battleship activity sheets, the Emojilicious Coordinate Stories, the coordinate plane guided notes, the City Planner worksheet, and the zombie hunting activity. The researcher examined the student work for trends in achievement among the students. Some of these trends included common student errors, percent completion, attention to detail, and overall grade for each piece of work.

Video Recordings. During the daily classroom activities, the teacher-researcher walked around the room with a notepad and made bullet point notes based on student engagement, student participation, and students' interesting comments or ideas. Following the data collection period, the teacher-researcher coded these notes for themes surrounding student achievement. Additionally, the teacher-researcher positioned a still video camera in the classroom each day to record teacher instruction and daily activities. As the teacher-researcher reviewed the data, she examined the videos and made notes on any details or student comments that she missed during her field notes for that day.

Results and Discussion

Measures of Attitude.

Daily Attitude Surveys.

The questions on the survey were examined for common trends through open, axial, and selective coding methods. The baseline set of surveys, handed out before game intervention, was coded separately from the post-intervention set of surveys. Average percentages were calculated from the twenty-four students who took the survey each day. On these baseline surveys, fifty-four percent of students mentioned they disliked math, while sixty-seven percent of students

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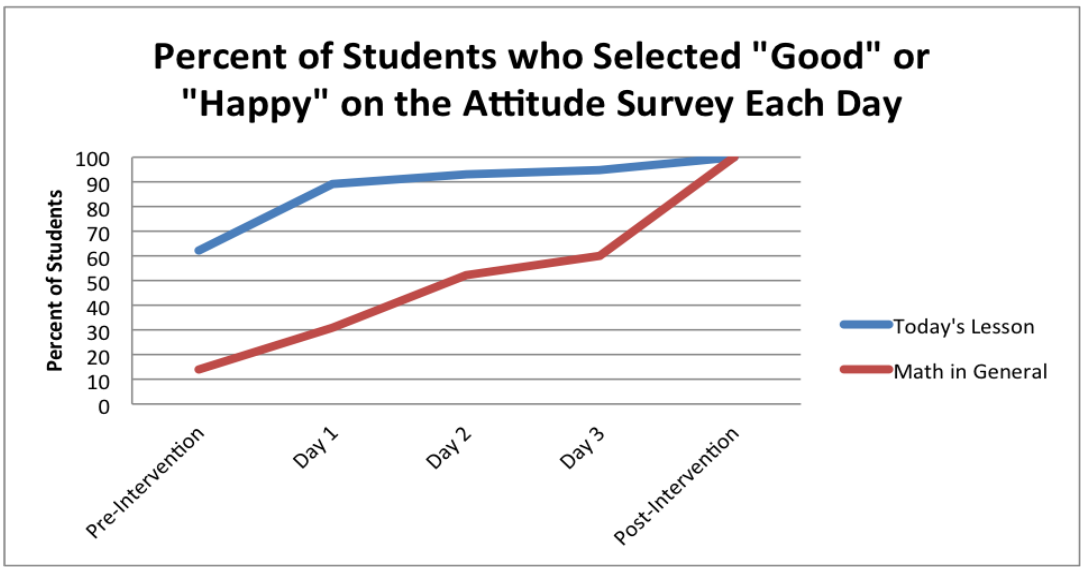
wrote they were bad at math. Only seventeen percent of students who participated in the survey said they enjoyed math. When examining the Likert-scale questions, eighty-three percent of students circled unhappy, worried, or bored about their feelings toward math on the baseline survey. Ninety-two percent of students' comments and reactions grew more positive each day. By the final day of instruction, one hundred percent of students indicated they felt either good or happy about math.

Figure 1. Graph of Survey Data



The results from the survey were overwhelmingly positive. The data revealed that not only did the students enjoy the game-based learning practices, but they also began to change their entire attitude about mathematics in general.

Student Interviews. All seven of the students pulled out for individual interviews commented on how much more they enjoyed math when it was taught in the form of a game. The three major trends that arose from the interviews were increased growth mindset, problem solving skills, and student engagement. In terms of growth mindset, the students made comments such as, “I am getting so much better at math now,” and “I learned a lot about ordered pairs. I didn’t know it was possible but I understand so much more now." These comments show that the students have begun to view their math ability as fluid, or something that could be developed through hard work and dedication. Many of the students who originally believed they were simply bad at math claimed in their interview that they now believe they can succeed with more fun and engaged practice.

Another common theme that arose from the interviews had to do with the problem-solving skills that were strengthened through partner interaction. When asked if the students enjoyed working in partners, one claimed, “Yeah, I like working in partners ‘cause I think differently from a lot of people. So having a partner is great because if I think one way about something and they think a different way, we can put our ideas together and hopefully get something right.” Many other students echoed this sentiment with comments such as, “I liked being able to talk out loud while I was thinking,” and “my partner got confused one time but I helped her think through her mistake.”

The final common trend from student interviews was increased student engagement during various classroom activities. Some of the comments that expressed this sentiment were, “I feel good about using games to get kids to learn math in a fun way,” and “learning math is not my favorite but this week I loved it! Usually I don’t, but this week was great.” Another student added, “learning math can sometimes be hard and stressful and I have problems with stressing. When I get too stressed or worried my asthma gets bad and that scares me.” However, “this week made math feel like there was no pressure because everyone was having fun while they were learning”. She mentioned that the game-based style of the math lessons increased her enjoyment of mathematics and her willingness to try.

Still Photographs and Researcher Field Notes. Each day during instruction, the researcher circled the room and briefly noted comments about student attitude. While these notes carried important information with which the researcher could use to look back at each day, they contained very limited data on whole-class student attitude. On the other hand, the pictures that were taken daily on the digital camera revealed details about daily student attitude. Of the seventy-three photographs that were taken by the researcher during the course of the unit, there are four wide shots of all the students in the room that are very telling in terms of student engagement and achievement. In each of these photos, every visible student is completely on task.

Measures of Achievement.

Content Assessment. Data on student achievement in ordered pairs was collected through student assessment at pretest, midtest, and posttest. See Figures 2 and 3. The average student score on the pretest assessment was 55.95 percent. This average was calculated from the scores of the twenty-three students who took the pretest. The scores for the pretest ranged from fifteen to seventy-five percent.

On the midtest assessment, the average score was 86.38 percent. This score was calculated from the twenty-three students who were present to complete the midtest assignment. The scores for this midtest ranged from sixty-five to one hundred percent. Twenty out of twenty-one students who completed both the pretest and the midtest saw an increase in their score from one to the next. The average increase from the pretest to the midtest for all individual students was 29.68 points.

The average posttest score was 96.14 percent. Twenty-four students were present to take this posttest in class. The scores for the posttest ranged from seventy-five to one hundred percent. All students, with the exception of one, saw a large increase in their score from the pretest to the posttest. The average individual score increase was 39.5 points from the pretest to the posttest.

Figure 2. Content Assessment Scores

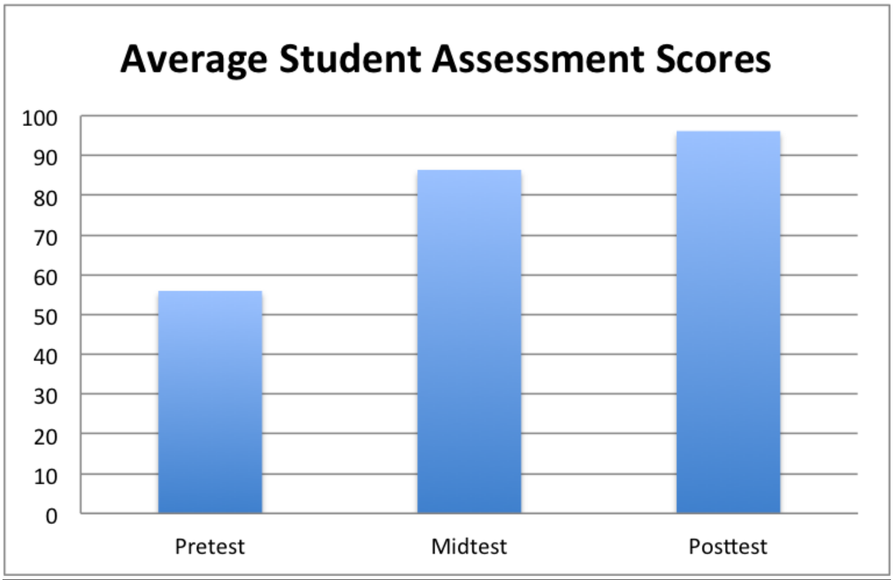


Figure 3. Change in Student Scores

Assessments	Average Change in Individual Student Score
Pretest → Midtest	29.68 %
Midtest → Posttest	9.57 %
Pretest → Posttest	39.50 %

Artifacts. The many artifacts consisted of all the written work that was done by the students throughout the week. These worksheets and assignments were then examined by the researcher and given a grade both for effort and for accuracy. On the first day of instruction, the students all played Coordinate Battleship and handed in their worksheets at the end of class. The class average for the battleship activity was an 84 percent. On the final day of instruction, the students rotated through five separate stations where they completed various activities and games dealing with the coordinate plane. The students demonstrated proficient knowledge of ordered pairs during the various games and worksheets. There were only 11 worksheets out of a total of 122 that contained any errors with the ordered pairs. This would translate to a class average of 91 percent for the day.

Video Recordings. Throughout instruction, the video camera picked up on many comments and conversations the teacher-researcher would have missed otherwise. The teacher-researcher classified interesting comments from these video clips as either "aha moments," declarations of ease, or peer corrections. The recordings categorized as "aha moments" include student comments such as, "Ohh, that makes sense now," "Oops, I did that one wrong," and "Good point. I didn't think of that before!" These comments are clearly indicative of students thinking through their mathematical understandings. They also show the value of collaborative work as the conversations with peers result in deeper thinking. Some of the comments from the declarations of ease category include, "I'm so good at this kind of math," "Look! We didn't make any mistakes," and "This is so easy." Again, this collaborative context is motivational for students. Finally, some of the most interesting comments in the peer corrections category include, "No, three comma four means over three *then* up four. You had it the other way around," "I think that ordered pair might be backwards," "Are you sure I didn't sink your ship yet?" and "Did you double check number six?" So, competition does not negate collaboration. Students worked together to clarify their understandings.

Conclusion

In the interviews and surveys, many of the students expressed an initial aversion to math that was lessened throughout the course of the game-based learning. They spoke of a looming sense of fear toward daily math instruction. These feelings of math anxiety that students expressed closely resembled those described by Hunt (1985). The negative attitudes that students felt toward math on the baseline surveys also went along with the research from Leroy and Bressoux (2016), who determined that students who struggle with low math self-esteem are the most likely to have poor achievement in the math classroom.

Data from student interviews revealed attitudes indicating that incorporation of serious games was successful because the games "make math feel like it's not math," and pushed many students "to work harder than [they] normally would because the work was fun and challenging." The game-based learning process allowed the students to work together to tackle complex, real-world situations. Many of the students commented on how having a partner was very beneficial to their overall success with ordered pairs.

Students exhibited a clear improvement based on the growth mindset model as described by Boaler (2016). They were more open and resilient as they developed skills and concepts. The comments and corrections that students made during their conversations showed they had developed a fundamental understanding of ordered pairs and the coordinate plane. The students felt comfortable enough with the material and the collaboration to not only correct their partner but to also explain why their partner's thinking was invalid. These various examples, coupled with the dramatic increase in students' assessment scores, showed the game-based learning increased both student attitude and achievement in mathematics.

While the results from this study seem to suggest that there is a strong relationship between game-based learning and student attitude and achievement in mathematics, there are important limitations to note. This study was limited in the areas of size, duration, and content. The results from the study represent the findings from one sample of students during one week of the year, focused on one unit of the curriculum. In order to gain more significant insight into the effects of GBL on student attitude and achievement and to control for potential extraneous variables, more research should be conducted.

The results of this study have many implications for teachers and students in the math classroom. The participants demonstrated significant improvements both in their attitudes about math and their achievement in ordered pairs. Thus, this action research study corroborated the literature surrounding the positive impact of serious games on attitude and achievement. These results may encourage other researchers and practitioners to continue investigating. The teacher-researcher author will definitely continue investigating and integrating game-based learning into instruction on a regular basis.

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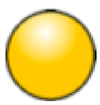
Appendix A: Attitude Survey (author-created content)

Name: ______________________________ **Date:** ______________

1. Circle the Emojis that represent how you feel about **today's lesson** (feel free to choose more than one):

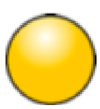
Unhappy Worried Bored Surprised Good Happy



Other: ______________

2. Circle the Emojis that represent how you feel about **Math in general** (feel free to choose more than one):

Unhappy Worried Bored Surprised Good Happy



Other: ______________

3. What else would you like to tell me about learning math?

____

____

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Appendix B: Emojilicious Coordinate Story (author-created content)

Name: ______________________________________

MY EMOJILICIOUS COORDINATE STORY

Rules:

1. Start at the origin
2. Use at least 15 emojis in your story
3. Draw your path and write down your coordinates for the emojis before you begin writing

Your story must begin with, "You will not believe what happened to me this weekend!"