Comparison of student achievement, understanding, enjoyment, and motivation in mathematics units for high-achieving fifth graders with and without creative problem solving games

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Abstract

Students in our public schools often struggle to create deep, personal meaning regarding mathematical concepts. Perhaps our students do not spend enough time studying mathematics during the day. Perhaps our teachers do not have a deep understanding, which leads to problems in teaching at a deep level. Or perhaps our students simply are not motivated to study the subject at a deep level because it does not seem interesting. In this pretest/post-test repeated measures study of 24 fifth grade students in a grade-accelerated mathematics class, a link between achievement scores and understanding of mathematical concepts through the use of invented games was explored. These games were used in place of traditional concept review activities before the post-test. Data indicated no significant difference in the post-test scores between conditions (game use, no game). Although the conditions were randomly assigned, pretest scores for the units in which games were used were statistically lower, indicating higher difficulty in those mathematical concepts. Therefore, students evidenced much higher gain scores in the experimental condition with a large effect size. Students spent a week of class time planning, building, and playing the games (in effect, reviewing the topic) before the unit test, while that time was used in direct instruction and traditional review in the control condition. The use of games was effective in increasing understanding for difficult topics among students in the group. While there were no significant reported differences in the students' levels of enjoyment, understanding, and motivation of the units in both conditions, there was a strong reported occurrence of students enjoying the challenge that the games units provided. I recommend that teachers implement invented games in mathematics classes to increase motivation, inject creativity, promote problem-solving, and to provide engaging practice in mathematical concepts.

Comparison of Student Achievement, Understanding, Enjoyment, and Motivation in Mathematics Units for High-Achieving Fifth Graders with and without Creative Problem Solving Games

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Abstract

Students in our public schools often struggle to create deep, personal meaning regarding mathematical concepts. Perhaps our students do not spend enough time studying mathematics during the day. Perhaps our teachers do not have a deep understanding, which leads to problems in teaching at a deep level. Or perhaps our students simply are not motivated to study the subject at a deep level because it does not seem interesting. In this pretest/posttest repeated measures study of 24 fifth grade students in a grade-accelerated mathematics class, a link between achievement scores and understanding of mathematical concepts through the use of invented games was explored. These games were used in place of traditional concept review activities before the posttest. Data indicated no significant difference in the posttest scores between conditions (game use, no game). Although the conditions were randomly assigned, pretest scores for the units in which games were used were statistically lower, indicating higher difficulty in those mathematical concepts. Therefore, students evidenced much higher gain scores in the experimental condition with a large effect size. Students spent a week of class time planning, building, and playing the games (in effect, reviewing the topic) before the unit test, while that time was used in direct instruction and traditional review in the control condition. The use of games was effective in increasing understanding for difficult topics among students in the group. While there were no significant reported differences in the students' levels of enjoyment, understanding, and motivation of the units in both conditions, there was a strong reported occurrence of students enjoying the challenge that the games units provided. I recommend that teachers implement invented games in

mathematics classes to increase motivation, inject creativity, promote problem-solving, and to provide engaging practice in mathematical concepts.

CHAPTER 1

INTRODUCTION

Mathematics is all around. From managing household finances to getting better values at the supermarket to mixing recipes for delicious cupcakes, numbers are a fact of life in contemporary America. In the past, this level of mathematical skill might have been enough for a person to compete and thrive in a local, agrarian society. However, as technology links our world more seamlessly and competition becomes increasingly global rather than just local, our students must become more proficient in the language of engineering, technology, and the virtual marketplace. This language is mathematics and mathematical reasoning. Mathematics education in America finds itself at a crucial moment. The American public school system can choose to continue covering a multitude of standards with little depth or it can choose to explore connected mathematical topics with depth and understanding, addressing all the benchmarks organically along the way. I would much rather take the second approach.

In this master's level research project, I investigate the link between achievement scores and topic understanding in mathematics through the use of games invented by students. These games all contained elements of variability and became increasingly creative and complex as the project progressed. To measure my results, I investigated pretest-posttest scores and after-unit attitude surveys. Additionally, I asked the students to complete an alternate assessment that involved problem finding, rather than just problem solving, in an attempt to make a stronger link between creativity and understanding in the topics studied.

Importance of Teaching Creative Problem Solving Skills

This research is important because new mathematics assessments call for increased problem-solving skills and higher levels of thinking. A current movement across the United States is toward Common Core standards (Levin, 2010) in mathematics. Assessment of these standards occurs through newer formats of multiple choice questions with multiple correct answers and other questions in which students are asked to find an error and explain why it occurred or what should be done instead. Various other higher-order thinking questions beyond analysis and evaluation are also planned for these assessments. The current repeated measures study will examine the effects of having students practice new mathematics concepts through making open-ended problem-solving games related to the content and by assessing student learning through the more complex formats just described. The results of this research investigation will be of interest to school districts and to others who are curious as to how to help students develop greater thinking skills and understanding in the area of mathematics.

Personal Interest in the Topic

As a teacher, mathematics has been my primary focus. I admit that I did not initially choose to teach mathematics because of a deep love of the subject. Instead, I chose to pursue mathematics in my educational career because I saw a lack of teachers at the elementary level paying any attention to the subject. Nearly all my peers in undergraduate education were pursuing reading specialties and endorsements and nearly every teacher I worked with in practicums and other experiences openly admitted to having little to no deep understanding of math. I took this as a sign that I needed to do what I could to become an elementary teacher that did understand mathematics to help my students become functional mathematicians, in spite of some of the anti-mathematics biases they might have encountered at home and in earlier classrooms. Throughout my graduate education, I have paid particular attention to the idea that students learn best when they have some agency in the process. This project is a chance to measure how students respond to not only having control over the end-of-unit review sessions for some units of instruction, but also the ability to inject creativity into mathematics. During this process, I was teaching in an urban fifth grade classroom in Iowa. My mathematics class was a higher achieving group of 26 students that had been accelerated into sixth grade math.

Statement of the Problem

Because students often do not view themselves as creative in the domain of mathematics (Kaufman, 2004), the creation of games to review concepts and practice skills might help to cement ideas and provide the opportunity to engage in creative thinking. The following research questions will be investigated by this study:

How does student comprehension of mathematical concepts differ when students create problem-solving mathematics games to practice the concepts and share these with classmates?

How do student-perceived understanding of the mathematical topic, enjoyment of mathematical schoolwork, and motivation to learn mathematics differ when students create problem-solving mathematics games to practice the concepts and share these with classmates?

Terms Related to the Study

Problem Finding. The discovery or creation of problems to be solved (Getzels, 1979).

Problem Solving. Resolution of dilemmas through contemplation, knowledge, or skill (Getzels, 1979).

District Benchmark test. These tests are given at the end of each unit of mathematical study across the Des Moines Public School district. Every 5th grader takes the same test as a way to compare achievement across the 38 elementary schools in the district.

Repeated Measures. A method of sampling in which the same subjects are measured in every phase of the research. In this case, both the control and experimental conditions.

CHAPTER 2

LITERATURE REVIEW

Preview

In preparation for this project, I chose examine several topics related to invented games in mathematics. It made sense to see how other researchers had approached the use of games in teaching math. I also was curious to see what has been written about creativity in math. Additionally, as my project addressed play in older students, I wanted to know if anything had been written regarding developmental play after preschool and the primary grades. Finally, I investigated how problem finding has been incorporated in education. With this background knowledge, I was better able to contextualize my own research.

Use of Games in Teaching Mathematics

As an elementary student in the late 1980's, I remember playing mathematics games occasionally in my classrooms. Most of these games involved cutting out cards, laying them on a table, and matching them into some specified sequence. They were barely more engaging than the worksheets we did the rest of the days, but sometimes, barely is enough. Mathematics games of the past involved cards, boards, and concrete rules with limited problem sets and fewer options. Early computer games fit this same pattern—they were ostensibly card games displayed in pixels. However, technology has continued to develop and has allowed games to become more customizable, variable, and personal. This variability has allowed games to become much more effective in exposing children to many more problems per day than simple worksheets allowed (Lee, 2004), in addition to allowing immediate feedback. Lee (2004) also found that students routinely increased the difficulty in their games without direct instruction to do so, suggesting that the use of computer games became a motivating factor in students actively taking risks in practicing mathematics facts. These results were commonly reported by researchers in this area. Computer games, as early as 1992, were found to "produce significant gains in mathematics achievement for students in first grade through junior high school" (Randel, 1992).

The games with which my students were operating, however, were not computer-based (except for a few very interesting examples). Due to a lack of equipment and time, our games were primarily card- and board-based. The teacher gave the students direct instruction on how to make games variable from play to play, how to make them easier or more difficult, and how to allow the game to develop through experience. This allowed the games to behave more like a modern computer game, while still being simple enough to build in a few days with items regularly found in a classroom. Fengfeng (2008) reported that many games that are commercially available lack connection to the curricular goals that students need to meet to succeed in our current climate of high-stakes testing. Our games had the advantage of being directly linked to the prioritized standards of each unit by requiring the students to build each of the standards into their play.

Integrating Creativity into Mathematics and the Curriculum

By allowing the students to create games of their own, it became necessary to explore the idea of whether creativity is domain-general or domain specific. In other words, are creative people creative in all aspects of life or are they only creative in certain domains and merely average thinkers in other aspects? What if there is a third option?

What if there were certain creative thinking skills that transcend domains and permeate thought, yet are enhanced by other domain-specific creative skills (Kaufman, 2004). Baer (2005) goes on to wonder if perhaps creativity is too big an idea to be free from domains, that it cannot be entirely "free-floating and abstract" and must anchor in some content or another.

However we choose to look at creativity, one idea seems to commonly override the rest: creativity in mathematics is very rarely self-reported. When Kaufman (2004) asked college students to assess their creativity in a variety of domains, students who viewed themselves as generally creative also consistently viewed themselves as creative in a wide swath of areas. The only area that did not consistently correlate with general creativity was mathematics. The author of this study suggested that, perhaps, many people simply do not see mathematics as an area in which one can be creative. Rather, it is a domain that is dominated by rules that must be followed and algorithms that will not bend. I suspect mathematicians throughout history might argue that this is not the case, but for many students in the general public it seems completely reasonable that few people can work creatively in mathematics (Papert, 1972). Is it possible that the use of invented games could help students to think of mathematics as a creative endeavor?

Developmental Play as a Way to Learn

Many studies have examined the role of play in education, but most of these have focused on very young students (File 1994, Bergen 2002, Ailwood 2003). Few have examined the potential utility of play for students as they reach the upper elementary and middle grades. Vygotsky (1966) described imagination as a "new formation which is not present in the consciousness of the very young child, is totally absent from children, and represents a specifically human form of conscious activity." If imagination is a uniquely developed quality of human consciousness, why have our schools tried so hard to remove it from learning? My look into using games to make mathematics more interesting stems from a desire to add imagination to mathematics work and allow the students a chance to build on the ideas they had been learning.

Researchers have shown the benefits of play in early childhood education (Isenberg 2002, Bergen 2002). These benefits include the development of fine and gross motor skills, interpersonal communication, negotiation, goal seeking, and problem solving among many others. However, school districts across the country continue to further emphasize proficiency test performance and the race to make children meet a variety of benchmarks which has caused most social pretend play and "choice" time to disappear from kindergarten classes. Bergen (2002) declared one of the major challenges facing play proponents in early childhood education to be the ability of educators to clearly articulate how the cognitive skills that children develop during pretend or structured play impact future learning more than just memorizing the standardized information presented in existing curricula. Hyvonen (2011) looked into play in schools and noted that one of the primary difficulties in putting play into classrooms is that many teachers struggle with the belief that play and learning are two separate concepts that are mutually exclusive. This might be true if play is viewed as a strictly imaginative, no rules free-for-all. However, "affording play" (play with elaboration and assessment) with the teacher acting as facilitator, advisor, observer, and encourager can help bridge the gap between play and learning (Hyvonen, 2011). Through my use of affording play, I hope to add a bit of articulation to the discussion in terms of using invented games in mathematics and the positive effect I found in my academic units.

Problem Finding as Higher Order Thinking Assessment

Part of this project was an attempt to inject creativity into mathematics for upper elementary students. Many people do not view mathematics as a canvass that can be decorated with creativity (Papert 1972, Kaufman 2004, Mann 2006). Mathematics is typically viewed as sets of rules to be memorized and algorithms to walk through. However, mathematicians tend to view these rigid boarders in another way. Rather than being limited-use functions for finding out when two trains will meet or how steep a line is, they tend to see these mathematical principals as tools for unlocking the mysteries of economics, space travel, and even baseball. Mathematicians would probably argue that instead of being supremely rigid, mathematics is actually an infinitely creative endeavor.

The difference between the layperson and the mathematician is that mathematicians are experts at problem finding, rather than just problem solving. In fact, as Getzels (1979, p. 170) stated, "It is…the discovery and creation of problems rather than any superior knowledge, technical skill, or craftsmanship that often sets the creative person apart from others in his field." Problem finding becomes the most important aspect in setting average scholars, scientists, artists, and whomever else apart from the outstanding. Getzels (1979, p. 168) went on to insist that "after the problem emerges, the skills of the artist (and the same holds true for the scientist) take over." Lee (2007, p. 113-114) agreed that problem finding is an integral piece of problem solving, stating that, "Problem finding leads to more effective, innovative, and creative problem solving because it allows problem solvers to search for new problems and sub-problems continuously." In effect, people (especially students) are more invested in solutions when the problems stem from their own ideas and observations. Lee would consider my alternate assessments to be moderately structured problems in which the goal is evident, but the individuals must identify and rectify the situation.

Summary

The identified literature allowed me to explore many interesting ideas in relation to the use of games in the classroom, imagination, creativity in mathematics, and how to blend learning and play with students in the elementary grades. These readings confirmed that children are motivated to challenge themselves through game play in mathematics by engaging in more and increasingly difficult problems. My suspicion was also confirmed that many people do not view mathematics as an area in which one can be creative. Many mathematicians, statisticians, and engineers use mathematics creatively every day, yet most people believe that mathematics can only exist in a narrow window of opportunity. Another new idea included in the reading was that teachers often do not include play in their instruction because they do not quite know how to articulate how that play can benefit the students' learning. This project attempted to inject play into my class by having students invent games. Finally, the readings presented the idea of the importance of problem finding in the creative process. As teachers, we are trained and encouraged to develop the next generation of problem solvers. This is a noble goal, but it seems the real focus should be on developing problem finders so that there is something novel to solve in the first place. The ideas encountered in the literature helped to shape this project by opening many avenues of possibility that I had not previously considered.

CHAPTER 3

METHODOLOGY

Participants

26 students who were assigned to the author's fifth grade mathematics class were invited (24 consented) to participate in the study at an urban Iowa school. School district, student and parent/guardian written consent was obtained for all study participants. The sample included a population of 16 males and 8 females. 18 of the students identified as White, 3 Black, and 3 bi-racial. All students were aged 10 or 11 years old.

Research Design

A pretest-posttest repeated measures design was used in which the same group of 5th grade students alternated between a control condition for learning a mathematics topic and an experimental condition. The difference between the conditions was how students practiced the concepts – through traditional work on problems or through the creation of an open-ended mathematics game that addressed the topic. The design of the study is shown in Table 1.

All students took the district-provided pretest and posttest (district benchmark assessments) for each mathematics unit. We asked for student and parent consent to use these scores in the study. An additional short post-assessment that focused on higher-order thinking skills was also given for each unit. I used these scores in the study along with student responses to an attitude assessment shown in Table 2.

Table 1.

Design of the Study

Order	Approximate Dates	Mathematical Unit	Treatment
1	August-September	Ratio and Proportional Relationships	District benchmark assessment pretest on the topic: Control Condition: Traditional worksheets of problems for practice District benchmark assessment posttest on the unit Short higher-level thinking posttest on unit
2	October - November	Multiplication and Division of Fractions	District benchmark assessment pretest on the topic: Experimental Condition: Students practice by creating problem solving games District benchmark assessment posttest on the topic Short higher-level thinking posttest on topic
3	November - December	Multiplication and Division of Decimals and Percent	District benchmark assessment pretest on the topic: Control Condition: Traditional worksheets of problems for practice District benchmark assessment posttest on the topic Short higher-level thinking posttest on topic
4	January-February	Data and Statistics	District benchmark assessment pretest on the topic: Experimental Condition: Students practice by creating problem solving games District benchmark assessment posttest on the topic Short higher-level thinking posttest on topic
5	February-March	Geometry	District benchmark assessment pretest on the topic: Control Condition: Traditional worksheets of problems for practice District benchmark assessment posttest on the topic Short higher-level thinking posttest on topic
6	April-May	Expressions and Equations	District benchmark assessment pretest on the topic: Experimental Condition: Students practice by creating problem solving games District benchmark assessment posttest on the topic Short higher-level thinking posttest on topic

Table 2.

Student Interest Survey

Write the main mathematical topic of the

unit:____

Please circle a number below to rate your enjoyment of mathematics during the unit we just completed.									
1	2	3	4	5	6	7	8	9	10
Not enjoyable at all				Neutral					Very enjoyable

Please give two reasons why:

Please circle a number below to rate your understanding of this mathematics topic.

1	2	3	4	5	6	7	8	9	10
Did not understand it at all				Neutral					Understood it very well

Please give two reasons why:

Please circle a number below to rate how motivated you felt to learn more about the mathematics during this unit.

1	2	3	4	5	6	7	8	9	10
Not motivated at all				Neutral					Very Motivated

Please give two reasons why:

<u>Description of the Additional Short Assessments Given at the End of Each Unit:</u>

Each student was given a page with hypothetical student work on two mathematics problems shown. Each problem had an error. The student was asked to identify the error by circling it and by explaining the issues related to the error. An example of this assessment and the accompanying rubric is shown in Table 3 and Table 4, respectively.

Table 3.

Sample Alternate Post Assessment Questions for Unit 1

Example Question
Identify and Correct the mistake in each problem/statement. Explain the correction thoroughly using words, diagrams, or mathematics expressions: The Greatest Common Factor of 10 and 6 is 30.
Identify and Correct the mistake in each problem/statement. Explain the correction thoroughly using words, diagrams, or mathematics expressions: Marco is able to groom 7 dogs in 4 hours. If he groomed for 28 hours last week at this rate, he should have been able to serve 72 dogs.

Table 4.

Rubric for Scoring the Alternate Post Assessment

Criteria for Scoring Error Recognition Problem	Possible Points
Error Recognition	
Circling a place that is not an error	0
Finding a correct potential error	1
Finding the appropriate error	2
Error Explanation	
No explanation	0
Logical explanation but not really correct or applicable to the error	1
Logical explanation of one reason or aspect that is correct that is correct	2
In-depth correct explanation of what the error was and how it occurred or how to fix it.	3
Maximum Possible Points = 5	

CHAPTER 4

RESULTS AND DISCUSSION

Pretest and Posttest Scores

Pretest and posttest mean scores are shown in Table 5. Students performed just as well for each condition on the traditional posttest scores as evidenced by similar posttest scores (no significant differences were found). Although the units were randomly selected for each condition, the pretest scores show that those assigned to the game units were significantly more difficult with a large effect size ($p < 0.001$; Cohen's d=0.95). Students struggled on the pretests for two of the three game units. Specifically, they struggled with the Statistics Unit and the Expressions and Equations (Algebra) Unit with average scores of 28.5% and 53.5%, respectively. Students also struggled with one of the pretests (Geometry) in the non-games units achieving an average score of 48.1%. Overall, this shows that the game units were more difficult than the non-game units.

Posttest scores show that students, although starting at a disadvantage in the games units, achieved the same level of understanding. A paired t-test showed gain scores were significantly greater for the game units than the non-game with a large effect size (p <0.001; Cohen's d=1.21). Gain scores show students in the game condition were able to make a significantly larger jump in their understanding through the designing and playing of games. Although the students had less previous knowledge of the topics, the games activities allowed them to acquire equivalent understandings compared to topics learned in the non-game condition.

The alternate posttest assessment required the students to go beyond computation in evaluating and correcting the work of a hypothetical student. Therefore, this assessment examined a deeper level of student understanding. A paired *t*-test revealed a statistically significant difference between the scores of the posttest alternate assessment with a medium effect size (p=0.007; Cohen's d=0.56). This difference in scores across conditions is interesting because the assessment is different from the pretest in that it requires a greater depth of understanding and considering that the topics in the game units were more difficult, this could explain why the students had poorer performance on the alternate posttests.

Table 5.

Student Scores on Mathematics Content Assessments Comparing Units in which Games Were Used or not Used

Assessment	Game Unit Mean Score	Non-Game Unit Mean Score
Traditional Pretest (identical to posttest)	52.4 (11.7)	64.8 (14.3)
Traditional Posttest	87.3 (6.4)	87.0 (9.3)
Gain Score from pretest to posttest	34.9 (8.3)	22.3 (12.2)
Posttest Alternate Assessment	81.0 (11.2)	86.7 (8.9)

Student Attitudes

Table 6 shows the mean attitude ratings for the game and non-game units. Overall, the scores were fairly high for all ratings, regardless of the condition. Differences in mean ratings across conditions were non-significant. Understanding for both conditions was the same and reported to be higher than enjoyment or motivation. One potential aspect of working with a group of high-achieving mathematics students is that understanding would be high. It should be no surprise that enjoyment was lower than understanding, but it is a bit odd that the enjoyment was as high as it was, compared to attitudes in the general school population regarding mathematics (Furner, 2002).

Table 6.

Attitude Ratings for Game and Non-Game Units

Attitude	Game Unit Mean Rating	Non-Game Unit Mean Rating
Enjoyment of mathematics during lessons	7.9 (1.5)	7.6 (1.8)
Understanding of this mathematics topic	8.8 (1.2)	8.8 (1.4)
Motivation to learn more about the mathematics of the unit	7.9 (1.7)	7.8 (2.0)

Table 7 shows the mean student ratings of enjoyment for the game compared to the non-game units, along with reasons for these ratings. Fewer students mentioned liking the game topics (line 4 of Table 7), but students in both conditions expressed that they found the unit work (game and non-game) to be fun. During the games units, students more often reported enjoying the unit for being challenged (line 6).

Table 8 shows the students most often reported, in both the games and non-games units, the reason for their lack of enjoyment as boredom (line 1). Students in the non-games units also reported fairly frequently that they did not enjoy the unit because it was difficult or frustrating.

Table 7.

Frequency of Reasons for Rating Enjoyment of Units

Reason Given for Lesson Enjoyment	Example Statements	Game Units Mean Reasons	Non-Game Units Mean Reasons	Mean No. Reasons per Unit for All Units
Fun	It was very fun. We did many fun ways to learn it.	7.3	10	8.7
New learning	I learned new techniques. I never really did anything like this before. Now I know how to use fractions in math"	4.7	6	5.3
Easy	The test showed me how easy it was. It was very easy.	5.7	4.5	5.1
Liked topic	I love algebra. I really liked all the story problems. I like fractions.	1.7	4.5	3.1
Games	I really liked making the math games. I liked doing the review games. I made a fun game.	6.0	0	3.0
Challenge	It was really fun, but kinda hard. It was hard but cool. It was a challenge.	4.3	1	2.7
Proficient	I'm good at multiplying fractions. I can prove I'm smarter than my parents.	2.0	2.5	2.3
Interesting	This was an interesting math topic (statistics). Because there were interesting problems.	2.3	1.5	1.9
Sports	I like that stats are used in sports. We did lots of sports stuff. It was fun to learn about football stats.	1.3	0	0.7
Future use	I will use this in the future. It was a good thing to learn for the future.	0.3	1	0.7
Prior knowledge		0.7	0.5	0.6
Strategies		0.0	0.5	0.3
Homework		0.3	0	0.2
Organizing data		0.3	0	0.2
Variety		0.3	0	0.2
Technology		0.3	0	0.2

Table 8.

Frequency of Reasons for Rating Non-Enjoyment of Lessons

Reasons Given for Less Unit Enjoyment	Example Statements	Games Units: Mean No. Reasons per Unit	Non-Games Units: Mean No. Reasons per Unit	Mean No. Reasons per Unit for All Units
Boring, redundant or already mastered	Some stuff was too easy. It was a little boring.	2.7	4.5	3.6
Difficult or frustrating	It was kind of hard learning MAD (mean absolute deviation). There were a few data sets that were hard to do.	1.3	5.5	3.4
Not proficient or no prior knowledge	I'm not good at dividing. Some of it I didn't understand. It was a little too hard.	2.7	0.5	1.6
Confusing		0.7	2	1.3
Math not favorite	I just don't like math. Because I'm not a math fanatic.	1.0	0	0.5
Not fun/not interested	I didn't really find anything fun except exponents.	0.7	0	0.3
Time consuming		0.3	0	0.2
Homework- too much		0.3	0	0.2
Too much sports		0.3	0	0.2

Perceived Student Understanding of Mathematics

Table 9 shows that students in the games units most often reported understanding of the material by commenting that the material was easy or that they had significant prior knowledge (line 2). This rating is interesting when contrasted with the struggle students displayed on the unit pre-assessments. The students also reported frequently that they were proficient in the material. Since surveys were taken at the end of the unit, students evidently felt very confident after instruction and game construction had occurred.

Students most often reported understanding in the non-games units by stating that they understood the material and through teacher explanations (lines 3 and 4). Overall, the highest combined remark regarded the proficiency level of the students.

Table 9.

Frequency of Reasons for Rating Understanding of Units

Reason Given for Lesson Understanding	Example Statements	Games Units: Mean No. Reasons per Unit	Non-Games Units: Mean No. Reasons per Unit	Mean No. Reasons per Unit for All Units
Proficient	A lot of the operations were easy and understandable. I got a lot of answers correct. I feel I'm good at it.	7.7	6	6.8
Easy/Prior knowledge	It doesn't take that much time. It was very easy to learn. I got almost every answer right.	8.3	3.5	5.9
Understanding	I got most of it. It made sense to me. I think I understood most of it.	4.3	7	5.7
Teacher/explained	Everything was explained thoroughly. After the teacher explained it, it was easy. My mom helped me.	3.7	7	5.3
New learning	There were other people helping me. Once I learned it, it was easy. At first I didn't get it, but once I did, I learned a lot.	7.3	3	5.2
Liked topic	It was an interesting unit. I like math. I'm strong in math.	1.3	3.5	2.4
Effort	I kept working and practicing very hard. I tried really hard.	0.7	2	1.3
Practice	We practiced a lot. Lots of practice in class.	1.0	0.5	0.8
Strategies	We worked on strategies building up to a final graph project. Because we did many different ways to understand.	0.7	0.5	0.6
Fun	It was enjoyable.	1.0	0.0	0.5
Games		1.0	0.0	0.5
Peer help		1.0	0.0	0.5
Challenge		0.0	0.5	0.3

Table 10 shows that students in the games units reported not being proficient at the end of instruction as the primary reason for less understanding of the unit. This seems to be a logical conclusion in that the students who did not feel comfortable with the unit material were simply stating that their understanding could be higher if with further study.

Table 10 also shows that students in the non-games unit reported confusion or difficulty of the material as the reason for less understanding of the unit. Again, this stands to reason that an honest student would mark down her understanding if the material was difficult to master.

Table 10.

Frequency of reasons for rating non-understanding of lessons

Reason Given for Less Unit Understanding	Example Statements	Games Units: Mean No. Reasons per Unit	Non-Games Units: Mean No. Reasons per Unit	Mean No. Reasons per Unit for All Units
Confusion/Difficult	Lots of different methods, so it got confusing. I didn't get it for a while. It got confusing sometimes.	0.3	9	4.7
Not proficient	I didn't get when to multiply and divide story problems. I didn't have a perfect understanding. I still don't get the other ways to do the problems.	6.3	2.5	4.4
Already mastered	I already knew percentages. A tutor taught me a method that really helped.	0.0	1	0.5
Math not favorite		0.3	0	0.2
More still to learn		0.3	0	0.2

Student Motivation

Table 11 shows that the most commonly remarked reason for high motivation during all units was learn more/new learning. High achieving students are often motivated by gaining knowledge and this group was no different. It is interesting to note that the creation of games was only noted one time per unit (in the games units) as a motivating factor (line 13).

Table 11.

Frequency of Reasons for Rating Motivation of Units.

Reason Given for Lesson Motivation	Example Statements	Games Units: Mean No. Reasons per Unit	Non-Games Units: Mean No. Reasons per Unit	Mean No. Reasons per Unit for All Units
Learn more/New learning	I wanted to be better. I felt I could do a lot more after learning it. I like to know a lot, so I was waiting for this unit.	5.0	6.5	5.8
Fun/Enjoyment	It was fun to learn about. I had fun doing it. It was a fun unit.	3.3	5	4.2
Future knowledge/use	I thought that if I learned this, I wouldn't have to learn it later. I was motivated to learn more because I will need to know this stuff later and now. I'll need this (stats) for stocks.	2.7	5.5	4.1
Like subject/Interesting	I knew it would be interesting. I liked the math. I really wanted to know about shapes.	2.3	5.5	3.9
Determined	I felt motivated because I wanted to understand it. I knew that it was a new math skill and I want to be as good at math as I can be. I knew I could do it.	2.7	4.5	3.6
Easy	It was easy. It wasn't very confusing. I got it right away.	2.7	1	1.8
Exciting	Very exciting. I started to have fun. I thought learning cool tricks for multiplying and dividing fractions was fun.	2.3	0	1.2
Competition	Sometimes I would have a race with my friends and see who could go the fastest in solving a problem. I wanted to get good grades. I was pushing myself.	1.0	1.0	1.0
Proficient	I already knew most of it. It was mainly powers and coordinate graphs (which I understood). I could solve problems quickly.	1.0	0.5	0.8
Challenge	It was a fun challenge. I got confused once in a while, but learned it through practice. I wanted a challenge.	0.7	1.0	0.8
Sports	I wanted to be able to keep (sports) player stats. I look at football stats. I need to know averages for baseball stats.	1.3	0	0.7
Confidence	I gained confidence. I knew I could do it. Once I knew stuff, I was motivated.	1.0	0	0.5
Games	We got to make games. The games were fun. I wanted to make a game.	1.0	0	0.5
Prior knowledge		0.3	0.5	0.4
Peer help		0.0	0.5	0.3
Pride		0.0	0.5	0.3
Technology		0.3	0	0.2

Table 12 shows that students generally remarked that the reasons for not being motivated to learn more during all units was because the material was confusing/not proficient/too difficult or that they were simply bored (lines 1 and 2). Several students per unit also remarked that there was little new learning (line 3) or that they had mastered the content (line 5).

Table 12.

Frequency of Reasons for Rating Non-Motivation of Lessons

Reason Given for Less Unit Motivation	Example Statements	Games Units: Mean No. Reasons per Unit	Non-Games Units: Mean No. Reasons per Unit	Mean No. Reasons per Unit for All Units
Confusing/Not proficient/Too difficult	I didn't know some things. It was kind of complicated. It was too hard at first.	1.0	3.5	2.3
Boring	It was too easy. It wasn't motivating. I thought it was fun at first, then it seemed like we repeated over and over and over.	2.0	2.5	2.3
Little new learning	There's not much to learn. I wanted something new. I felt like I already knew everything.	1.0	2.0	1.5
Not interested	When I learned it, I didn't seem to care. I didn't really know anything about statistics and I didn't want to do anything new. There are lots of parts I dislike.	2.0	1.0	1.5
Already mastered	I think I already understood it pretty well already.	2.0	0.5	1.3
Prefer other subjects	I wasn't looking forward to the math every day. It was not my favorite topic. I never want to learn math.	0.3	1.0	0.7
Disappointed	I learned some last year--I thought that if I learned this, I would not have to learn it again.	0.3	0.5	0.4
Did not feel important		0.0	0.5	0.3
Time consuming		0.3	0.0	0.2
Poorly paced unit		0.3	0.0	0.2

Games

The games that students constructed over the course of the project continually impressed me. I expected games to be very simple, straightforward, and a little repetitive. I thought that with each unit I would find a couple of dice games, a couple of "draw a card" games, and a few simple board games with mathematics problems on certain spaces. While I did see some games of exactly these types throughout the school year, I also saw games that were increasingly complex, intricate, and impressively designed as the students gained experience making games and learned that they were truly free to make games that they would actually like to play.

The simplest game types made by students in this study involved only one type of variability and little imagination. Often, these games involved rolling dice or drawing a card to fill in a portion of a number sentence that a player had to then solve for points. An example game of this type is shown in Figure 1. Occasionally, these games would pit players against each other or against a clock in a race. These games did appear in each of the games units, but after the first games unit they became less frequent.

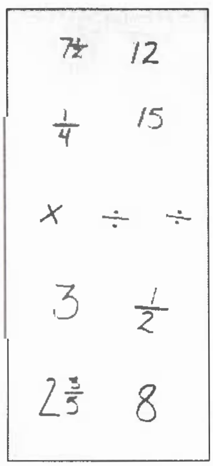

Figure 1. Mathematics Game in which Students Draw a Card to Complete a Mathematics Problem and Then Solve It.

The next evolution of games was a wide array of board games. Some of these were very basic "Candyland®"-type games in which a player rolls a die, moves around a board, and encounters various obstacles and benefits on different spaces. Examples of this type of game are shown in Figure 2.

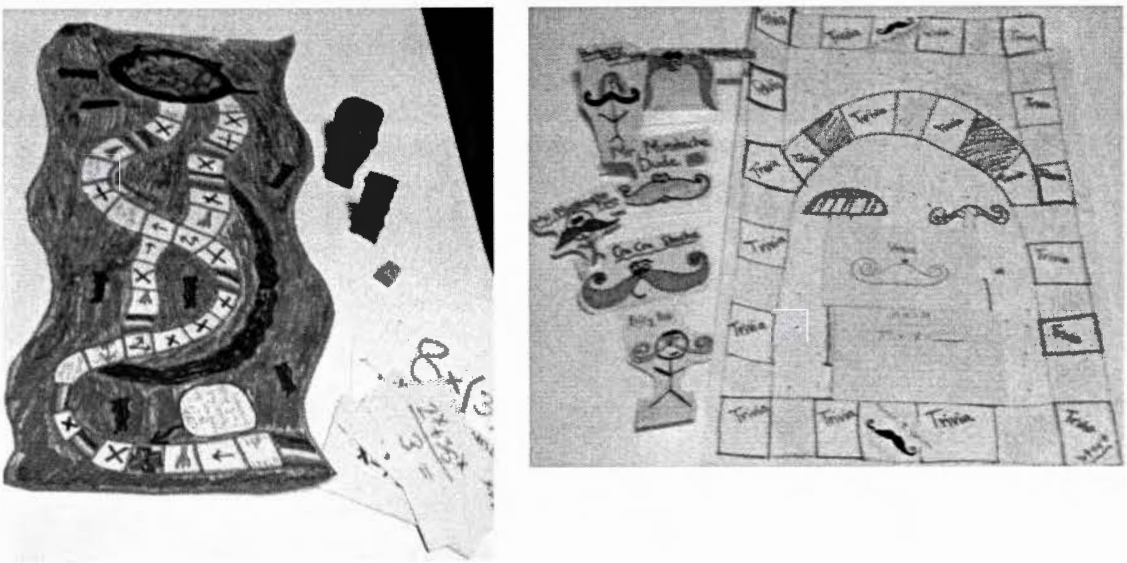

Figure 2. Examples Candyland®-type games

Some of these board games included elements of game play that had nothing to do with mathematics, such as trivia questions about Taylor Swift in "The Swift Challenge." See Figure 3. These games were quite popular and were the most commonly produced type. One reason the students liked to make this type of game was that they were able to create outlandish concepts with fun features while being able to easily incorporate mathematics review into the play.

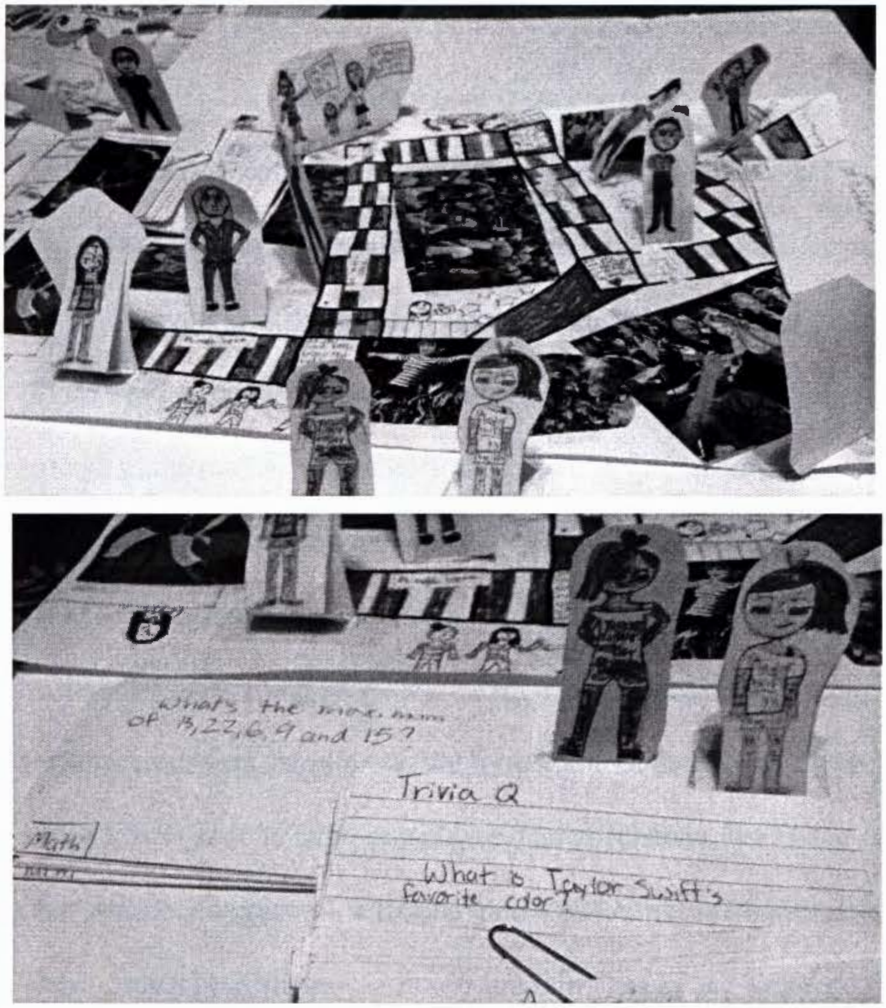

Figure 3. Images of the Game Titled, "The Swift Challenge"

Fortunately, some students took board games to a higher level of complexity. These games often included a board, but the board more resembled a map, such as in the games "Risk®" and "Clue®." The maps included treasure chests, one-way doors, and enemies (that were sometimes visible and sometimes hidden). Players chose certain characters with a variety of attributes relating to hit points, strength (manifest in the ability to retry missed problems), or many others that the creators invented. These games played as adventure or role-playing games and involved mathematics review in order to progress to different parts of the map, to defeat enemies, or to obtain treasure and items.

Unfortunately, I did not get any pictures of these games because the students who created them all wanted to immediately take them home.

The most complex games I observed during this project were a series of choose-your-own adventure type games during the final games unit. Several groups of students were interested in making video games for their last unit, but found quickly that they would need far more time than a few days to produce something with variability and enough mathematics review to fit the project requirements. Instead, we came up with a plan to put the game on a website with links that would lead from point to point with a variety of challenges embedded throughout. However, building websites also proved to be too time consuming so we settled on using PowerPoint (a program with which the students were very familiar) as the foundation of their games with hot buttons that jumped from slide to slide as a player made decisions. We ended up with a football game (that was not completed), a fishing game, and a treasure hunting game. See Figure 4. These games became very intricate and fairly massive. "Treasure Hunter" checked in at 45 slides and was very fun to play with good replay value.

In the end, I was very impressed with the students' creativity, attention to detail, and thoughtfulness in meshing mathematics review with fun, innovative games. Some games were simple, some were complex, but all were valuable in helping the students in this class master difficult mathematics concepts.

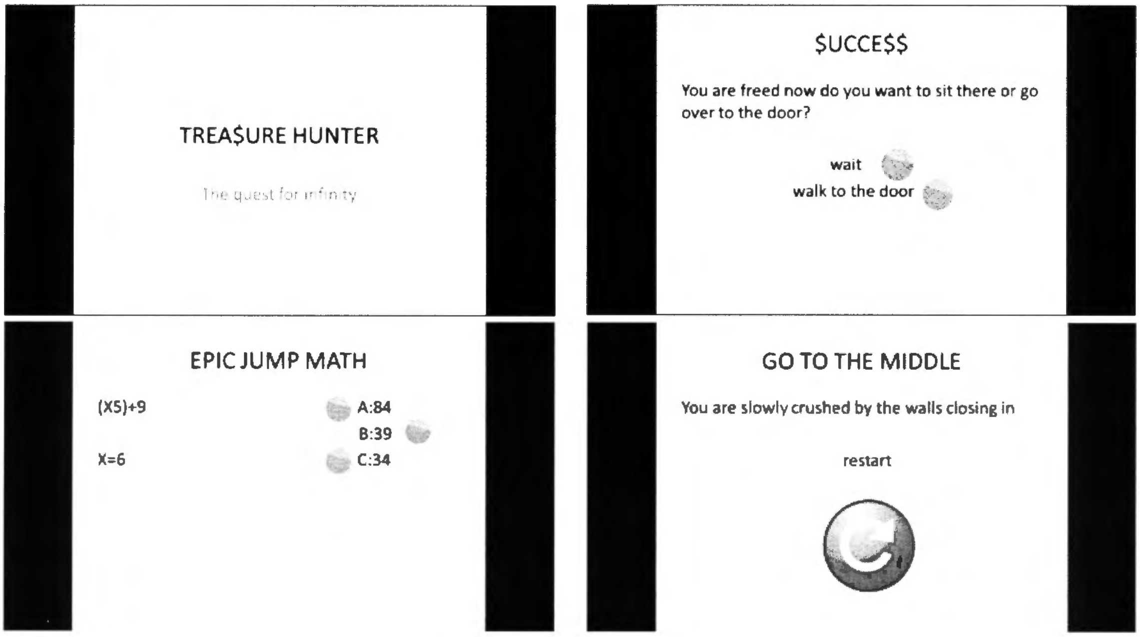

Figure 4. Example Game using PowerPoint Slides

CHAPTER 5

CONCLUSION

This examination of the use of games in helping high achieving fifth grade students better learn and comprehend mathematics showed significant gains in understanding during the games units when compared to the non-game units. These games were created by the students in small groups (2-4 students per group) to help the game players review key concepts from the unit. The games were to include some element of variability to make game play different in each use and were directly connected to the Iowa Core standards. Students typically took one week to plan, build, and play the games before the unit post-test was administered, then the alternate assessment and attitude survey occurred after the main test. The games units were randomly assigned, with the odd numbered units—first, third, and fifth—utilizing game play while the even numbered units used traditional test review and practice, plus a few extra days of direct instruction.

Through this process, the data show statistically significant higher gains in student understanding in the games units when compared to the non-game units. The students demonstrated that the games units were significantly more difficult through an analysis of their pre- and post-test scores (see Table 5). This result is particularly surprising when one considers that students effectively lost a week of direct instruction during the games units due to the planning, construction, and play time needed to bring the games to life. In addition, the students rated their enjoyment of all units quite high, which is not surprising because the students in the class were subject accelerated in math; however, the students were more likely to note that they enjoyed the games units because they felt challenged.

It is unclear whether this challenge was due to the games or the difficulty of the topics, so this question should warrant further research.

The results that emerged from this study indicate that there is certainly room in mathematics education for games, creativity, and developmental play at the upper elementary levels. In addition to students reporting enjoyment of the process of creating and playing the games, the gains they made between the pretest and posttests when compared to the non-game units were evident with large effect sizes. The pretest scores for the games units were significantly lower than for the non-game units, yet students achieved higher average scores on the posttests.

Recommendation

I encourage teachers, specifically mathematics teachers with students that are inquisitive and inventive, to use invented games in their instruction. While the sample size of this action research study is small, it has revealed statistically significant gains in understanding over the control condition.

The students were very engaged in the game-making process. They tried to generate more and more creative set-ups as the year progressed. We evolved from simple dice, card, and coin-flip games to expansive board games, adventure games with combat (e.g. enemies are damaged when students are able to solve problems), and even a few "choose your adventure" PowerPoint-based games with active links (these games were intended to be complete computer games until the students realized they could not code them in just a few days). My students looked forward to building games during each unit and were disappointed when I told them we could not build during some units because of the control condition. Even if the games had shown little or no increased understanding, a teacher would be wise to implement game creation into his or her classroom simply because the students were very excited to build and play a wide variety of original games. This level of engagement is hard to achieve in our schools, especially in mathematics, so, why not build a few games?

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