GAME BASED LEARNING IN MIDDLE SCHOOL MATH CLASSROOM

by

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of

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in

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DEDICATION

I dedicate this work to the children in my life, especially my nieces and nephew, who deserve the opportunity to learn about the natural world we live in, regardless of privilege or access. I chose to return to education and pursue my Master of Science in Science Education because in my adult life I was disheartened to see a complete disregard for science and a general lack of critical thinking skills among my fellow citizens. I would like to grow old in a society that values the pursuit of truth and understanding, and the conservation of our connections to the natural world that make us human.

ACKNOWLEDGEMENT

First, I would like to acknowledge my partner, Hannah Hayes, who has been an amazing peer editor and educational reference. Most important, her love and encouragement has been invaluable to me while I have been working on this project.

I must acknowledge my parents who have always supported and encouraged me to pursue my goals in education and science. Also, my siblings Adriana Velez Sellers, Claudia Velez White, and especially my brother John Velez, Ph.D. and his wife Melanie Sarge, Ph.D for their support and advice over the years of completing this project.

I owe a great deal of gratitude to the entire MSSE staff with a special thanks to Diana Peterson, John Graves, and Madeline Felts. Diana was like a "MSSE Mom" to me and helped me countless times with paperwork and advising. Madeline was of great service, taking care of the many daunting applications, registrations, and appeals required for graduation. Finally, John has been an amazing mentor during this process and has never once let me feel alone in this process.

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

ABSTRACT

Educational research has identified student enjoyment and self-efficacy as key aspects of student motivation, and as major contributors to student attitudes toward a particular subject. In addition, increases in both enjoyment and self-efficacy have been linked to game play participants in both recreational game play and game-based learning (GBL). This study investigated the effects of allowing student choice of game play format during GBL treatment sessions. For this action research study students in a math intervention course were allowed to choose their format of engagement in a GBL treatment. The treatment asked students to engage, in the game play format of their choosing, competitive, cooperative, or individually, with an online game designed to facilitate a gamified review tool and a gamified formative assessment tool. The researcher hypothesized that allowing students to repeatedly engage with the same game in the gameplay format of their own choosing would improve student attitudes about their enjoyment and confidence while learning math. Likert-type survey on attitudes about GBL and gameplay formats, student engagement metrics, and facilitator observations were utilized to capture quantitative and qualitative data throughout the treatment period. Analysis of data revealed that student attitudes improved in terms of their sense of enjoyment and self-efficacy while engaging in GBL during math class.

INTRODUCTION AND BACKGROUND

Context of Study

Over four years of my career, I taught as a math interventionist within the Bozeman School District before working in the special education department (SPED) in more recent years. Working as a math interventionist and within SPED allowed me the opportunity to work with students at all levels of intervention within the Multi-Tiered System of Support (MTSS). These experiences gave me great insight into education and a valuable perspective into current intervention practices. I realized during my experiences as a math interventionist that students who had struggled in the regular classroom, and thus had been identified as needing intervention, were typically hesitant to engage in the learning process because they lacked confidence in their ability to perform well in math. There are many reasons and causes for students to struggle within the educational system or simply to struggle within a particular subject which can lead to disengagement. These particular students seem to lack the ability to find enjoyment within learning, problem solving, or any academic challenges, even when they were able to be successful. Improving students' engagement and confidence became two of the most challenging aspects of working with students in the intervention setting.

Personally, I have always enjoyed games and solving puzzles so I began to use them during my intervention lessons both as learning tools and modes of engagement. Often, I found that by implementing game-based learning (GBL) within the intervention model, I was able to engage students who had given up hope of making progress in their own learning. Sometimes this was as simple as performing a mathematical card trick as a

"I can tell you what card you are holding - magic trick" in order to promote student thinking and engagement. Many of my intervention students began to look forward to our sessions because they wanted me to guess what card they drew out of the deck or because they wanted to perform the "magic trick" themselves. I found that while working with students who have behavioral or emotional issues, intervention sessions seemed less stressful when we were able to play a game of the students' choosing. In fact, the entire process became more enjoyable for both the students and myself; more importantly students began to demonstrate confidence in their abilities as they became more familiar with the games they played. However, one major problem within using GBL during my math intervention sessions became apparent when using competitive games during my small group intervention sessions. Many students were hesitant to engage in competitive gameplay for fear of appearing "dumb" in front of peers. Since one of my main goals as an educator is to instill self-confidence in my students this was a concerning factor. Many times, I would modify competitive games to be played in a cooperative or non-competitive format. This intervention work using GBL revealed an underlying obstacle for educators which is how to motivate or engage students who lack confidence in their ability to learn or do not enjoy engaging in the learning process. The value of GBL has been proven time and again, however I wish to further investigate the value of GBL in math intervention.

The purpose of this study was to examine the effects of using GBL in math intervention and assessment while allowing students multiple modes of gameplay engagement on student attitudes about their enjoyment and confidence learning math using GBL. Game play is an inherently engaging activity that the majority of individuals enjoy to some degree and thus has gained favor among educators. However, some individuals are more inclined to enjoy competition or cooperation than others for many various reasons, and as educators we must recognize the needs of individuals by accommodation and differentiation. This led to the question of how to engage students in GBL who are not comfortable playing games in traditional classroom settings.

Focus Question

The focus question for this study was, Will game-based learning improve student motivation to learn math?

Sub-questions included the following:

1. Does game-based learning increase student enjoyment and confidence in learning math?
2. Will game-based learning increase students' effort toward learning math?

CONCEPTUAL FRAMEWORK

Value of Game-Based Learning

Research on the impacts of game-based learning (GBL) via digital and non-digital games is a relatively new topic in educational research which has garnered a great deal of interest in recent decades. Researchers of games identified three main categories of digital games; games designed for entertainment, games designed for GBL, and serious games. Serious games, are typically designed for training purposes and focus on changing attitudes or behaviors of employees, and some researchers use the term Serious Game and GBL synonymously. These new games designed for learning instead of entertainment, have received a great deal of attention due to their ability to affect attitudes as well as their increased use and relevance in recent years (Ke, 2009; Sitzmann, 2011; Vogel et al. 2006).

Early investigations into digital games began with video games made for entertainment, widening later to include GBL and serious games. Early studies focused on the scope and nature of negative impacts on users from playing video games due to various aspects of violence represented in video games, as well as possible decreased pro-social behaviors (Anderson, 2004; Anderson & Bushman, 2001). Researchers quickly realized the motivational and sometimes addictive nature of videogames and began to wonder if this could be used in an educational setting (Connolly, 2012). Earlier research findings reinforced the motivating nature of digital games and presented the novel idea that game users could develop useful skills through gameplay (Subrahmanyam & Greenfield, 1994). More recent research has centered on the positive impacts and outcomes of digital gaming, such as gains in cognitive processes and the affective dimensions of gameplay on learning. This research is ongoing, however more recently some researchers have focused on the positive impacts on video game user psychology: motivational, cognitive, emotional, and social (Granic, Lobel, & Engels, 2013).

Several meta-analyses on GBL research give researchers and practitioners, who are new to this topic, access to a wealth of past knowledge and scientific inquiries into the subject. A pair of valuable meta-analyses focused on reviewing empirical research which identified evidence suggesting the positive impacts and outcomes associated with playing digital games on cognitive learning processes. These studies identified GBL's efficacy in aspects of learning such as content acquisition and retention and development of valued learning skills, as well as, the affective dimensions of learning such as motivation, behavior, and attitudes of the learner (Connelly, 2012; Wouters, 2013). Unfortunately, these early meta-analyses into GBL provide limited evidence for educational researchers and practitioners, due in part to the short comings in the objectivity of study designs. Out of over 7,000 studies found for one meta-analysis, only 70 provided the high-quality empirical evidence they required, and in the other meta-analysis in this literature review, 190 studies were initially identified with only 38 meeting researchers' criteria (Connolly, 2012; Wouters, 2013). These meta-analyses did reveal the literature on games was not well structured, comprehensive, or coherent and the need for more empirical studies.

In recent years researchers have been able to build on the precedents set by earlier studies and begin to refine their investigations to produce more empirical evidence and objective data with much less anecdotal based arguments. This is in part due to educational research findings that support active cognitive processing of educational content as crucial to student learning gains and retention (Wouters, Paas, & van Merrienboer, 2008). Most researchers in this field employ a mixed-methods approach to GBL research, which is dictated by the vast diversity of game formats and designs and further complicated by the interdisciplinary nature of modern curriculums. The meta-analyses reviewed here had inclusion criteria concerning methodologies and data collection which eliminated many studies from the results. While the meta-analysis performed by Connelly in 2012 focused primarily on the research of the games themselves, the meta-analysis performed by Wouters and colleagues in 2013 had an additional element in their analysis which focused on moderator variables. In the latter study, moderator variables such as; learning arrangements, group sizes, instructional domain, user age, number of training session, and level of realism, were coded and included in the data analysis (Wouters, 2013).

Student Enjoyment and Self-Efficacy

Building upon the foundation of constructivism, researchers and educators in recent years have become interested in the benefits of teaching students to become independent or self-regulated learners. Two key aspects of this concept include student self-motivation and student self-efficacy. Both motivation and self-efficacy have been shown to be key factors in student success and overall academic achievement (Jinks & Lorsbach, 2003; McPherson & McCormick, 2006; Zimmerman, Bandura, & Martinez-Pons, 1992). In 2011 researchers claimed that students' sense of self-efficacy in a subject such as science impacted the level of effort exerted by the student in the learning process and even in the level of coursework attained. They found these factors relevant for both students learning in a traditional classroom setting and those learning via GBL (Mikropolous & Natsis, 2011). The impacts of student academic self-efficacy have been found to last into adulthood with individuals making career choices based on what they feel they are capable of doing well (Cordero, Porter, Israel, & Brown, 2010; Gainor, 2006). In 2011, a study on the impacts of using GBL in Science, Technology, Engineering, and Math (STEM) curriculum which focused on student knowledge retention and self-efficacy found that, student self-efficacy increased regardless of playing conditions. In addition, these researchers found that student self-efficacy was increased to a greater degree when students were able to play learning games collaboratively (Meluso, Zheng, Spires, & Lester, 2012).

The field of GBL, despite being relatively new, has provided strong evidence for the efficacy of games as learning tools to be used in conjunction with more traditional teaching methods and learning media. Most studies reviewed within make the case that more research is needed to clarify the relationship between GBL and key learning factors such as student self-efficacy, motivation, and retention of knowledge. However, the majority are able to make confident conclusions about the value of GBL to promote general learning gains (Mayer, 2011). A recent meta-analysis confirmed the efficacy of GBL over conventional instruction methods with statistically significant results. This same meta-analysis revealed that the strength of their data depended on many different variables including, but not limited to, differences in moderator variables and GBL integration with conventional instruction methods (Wouters, 2013). These results and those from previous meta-analyses suggest that further investigation and research is needed to clarify the relationships between different GBL features and particular curriculum or cognitive skill retention, as well as student motivation and sense of self-efficacy.

METHODOLOGY

Demographics

This capstone project was conducted at Sacajawea Middle School (SMS) in Bozeman, MT, with a group of 23 sixth grade students who had been enrolled in a Math Access course during the 2019/2020 school year (N=23). Sacajawea Middle School has a student population of 864 students, with 316 sixth graders, 249 seventh graders, and 299 eighth graders. The demographics of this school are similar to those of Montana in general with 85.9% of students identifying as white or Caucasian. Bozeman is located in a rapidly growing region of South West Montana near Yellowstone National Park and several ski resorts. In addition to being a university town, Bozeman is a tourist destination for outdoor sports enthusiasts, with a predominately affluent population of 48,500, including approximately 16,766 Montana State University students. Sacajawea has a small population of students that receive free or reduced lunches, 11.9% which is mirrored in the 20% poverty rate among families in Gallatin County, Montana. SMS also has a relatively low population of students on Individual Education Plans (IEP) with only 11.8% of students qualifying.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A). The group of students included in this study had been identified as needing some level of math intervention due to their performance on assessments at the onset of the academic year, and were enrolled in a Math Access, a piece of the Multi-Tiered System of Support (MTSS). This Math Access course, which was taught by Ms. Lisa Fabian and Ms. LeAnne Lorenz, met for 25 minutes on Tuesdays, Wednesdays, and Thursdays in the mornings just before first period in the sixth-grade wing of SMS. The course was intended to address student's low performance and knowledge of 6^{th} grade math standards, primarily, in the content area of ratios, rates, percentages, understanding probabilities and statistical odds, the order of operations in equations, and working with fractions and negative numbers.

The Math Access course, which began in the last week of October 2019, was designed to run for 18 weeks. The teachers utilized multiple district approved math games that each focused on different sixth grade math skill standards or concepts. Ms. Fabian and Ms. Lorenz also presented the students with problem-based projects to complete over multiple class sessions. Throughout the duration of the Math Access course and the treatment period, students were both added and removed from the class for various reasons. In addition, some students were not present for particular treatment sessions and thus their data was missing on particular data instruments. Thus, only data collected for students present for both pre and post assessments were included in the data analysis (n=19).

Treatment

The treatment period began in December of 2019 when the students from two separate sixth grade Math Access courses joined together in order to create a larger group of students. The game-based learning (GBL) treatment, which ran for ten weeks, included the use of a trivia style game, Mathmagic, designed on www.playfactile.com, a free online service which allows users to design games resembling the television show

Jeopardy (Appendix B). The game was designed around the following 6th grade math standards and concepts; ratios, rates, percentages, understanding probabilities and statistical odds, the order of operations in equations, and working with fractions and negative numbers. Students earned points when they answered problems correctly, and could earn partial credit for incorrect attempts, which used correct strategies and concepts despite resulting in an incorrect answer. Each week students were presented with new math content or problem-based projects on the first two meetings and were asked to play the Mathmagic game on the third meeting of each week. The Mathmagic game treatment served as both a gamification of skill practice and problem-solving assignments as well as a formative assessment of student skills and knowledge.

Students were first introduced to the Mathmagic game playing as an entire class in five small groups. In this whole class format, each student was asked to quietly hold up a whiteboard showing their work and the correct answer. Students were allowed to assist others players on their own team as long as they did not write for their teammates. In this way teachers were able to access which students were capable of answering the questions and which were not. Students played the game as an entire class a total of three times, twice at the beginning of the treatment period as an introduction to the game and once at the end of the treatment period per their requests. During the fourth and ninth treatment sessions the students were asked to play the game individually and instructed to record their answers. During the fifth and sixth treatment sessions students were asked to make an individual choice about their own preferred gameplay format. Students were then divided by the teacher/facilitator into groups of four to five students based on individual student choice of gameplay format. Then the groups of students played the game competitively, cooperatively, or individually according to their previous personal choice of gameplay format. During the seventh and eighth treatment sessions students were asked to make an individual choice about their own preferred gameplay format. Students were then allowed to choose a partner to play the game with, given their partner made the same personal choice of gameplay format. Then the pairs of students played the game competitively, cooperatively, or individually according to their personal choice of gameplay format. In addition, during the eighth treatment session, after they made their individual choice about gameplay format, students were allowed to choose a partner to play the game with, given their partner made the same personal choice of gameplay format and they had not played the game together previously. The pair of students then played the game competitively, cooperatively, or individually according to their personal choice of gameplay format.

Data Collection and Analysis Strategies

Four data collection instruments were utilized during the treatment to capture both quantitative and qualitative evidence about the students' attitudes toward game-based learning in math class. At the beginning and the end of the GBL treatment, students in the Math Access course completed, The Student Enjoyment and Self-Efficacy Survey (SESS) which included 14 Likert items, 7 on their confidence learning math via GBL and 7 on their enjoyment learning math via GBL (Appendix C). The Likert items on the survey were focused on student confidence and enjoyment of learning math via GBL in general as well as with specific forms of engagement or gameplay format such as, playing independently, playing cooperatively, playing competitively, and playing games as a whole class. The students' responses on the SESS were scored using a Likert Scale of Strongly Agree (4), Agree (3), Disagree (2), and Strongly Disagree (1). The items on the Likert survey were treated as individual Likert items and analyzed with a Wilcoxon Signed-Rank Test with a calculated p-value to determine if any significant change in pretreatment and post-treatment responses was due to chance. The pretreatment and posttreatment average for each item were analyzed and normalized gains were calculated to determine the change in student responses. Normalized gains of less than 0.3 were considered low gains, 0.3 to 0.7 were considered medium gains, and normalized gains greater than 0.7 were considered high gains (Hake, 1998)

Within the first two weeks and last two weeks of the treatment period students completed the game individually as an assessment of their confidence in their own math knowledge. Students were instructed to answer at least six questions of their choosing from the game and record their answers on a provided Mathmagic Answer Sheet (MAS) (Appendix D). This assessment of their confidence in their own math knowledge collected quantitative data on students' level of engagement and effort on an assessment of the major sixth grade math standards. Any problem attempted by a student on the MAS was tallied as a point toward their confidence in math knowledge score. Since students were asked to answer at least six questions, two from each of three categories in the Mathmagic game, the range of this knowledge confidence score was six. The mean and median scores on the MAS for the pre and post assessment sessions were compared using whisker box-plots. A Wilcoxon Signed-Rank Test with a calculated p-value had a null hypothesis that any change the in the students' engagement score was due to chance. Also, the average student score from the pre and post MAS used to calculate normalized gains for the of questions students attempted. Normalized gains of less than 0.3 were considered low gains, 0.3 to 0.7 were considered medium gains, and normalized gains greater than 0.7 were considered high gains.

During each treatment session students were asked to make personal choices about their mode of engagement which was recorded in a Teacher's Journal (Appendix E). The record of student choices on their mode of engagement was analyzed and compared with student SESS responses. In addition, the Teacher's Journal was used to record notes on students' engagement and focus during treatment sessions. Student questions or comments about the game were recorded in the Teacher's Journal as well as teacher/facilitator notes about any off-task behavior observed (Table 1).

Table 1. Data Triangulation Matrix.

Focus Question	Data Source 1	Data Source 2	Data Source 3	Data Source 4
Primary Question: 1. Will game-based learning improve student motivation to learn math?	Pre and Post Math Knowledge Confidence (MAS)	Pre and Post Math Learning Confidence (SESS)	Pre and Post Math Learning Enjoyment (SESS)	Math Learning Focus (Teacher Journal)
Sub Questions: 2. Does game-based learning increase student enjoyment and confident for learning math?	Pre and Post Math Knowledge Confidence (MAS)	Pre and Post Math Learning Confidence (SESS)	Pre and Post Math Learning Enjoyment (SESS)	Math Learning Focus (Teacher Journal)
3. Will game-based learning increase student effort toward learning math?	Pre and Post Math Knowledge Confidence (MAS)	Pre and Post Math Learning Confidence (SESS)	Pre and Post Math Learning Enjoyment (SESS)	Math Learning Focus (Teacher Journal)

DATA ANALYSIS

Results

Student responses on the Student Engagement and Self-Efficacy Survey (SESS) showed that most students began the treatment period with positive attitudes about playing games in math class. Twenty-one percent of students strongly agreed when asked if they enjoyed math class more when we played games as part of our daily lessons in class and 58% of students agreed. (*n*=19). The remaining 21% of students responded negatively to this same item on the SESS about whether they enjoyed playing games in math class. At the onset of the treatment, students showed clear preferences on SESS items about their enjoyment of specific gameplay formats in math class. Items on enjoyment of cooperative, whole-class, and competitive gameplay received the most positive responses, respectively. On the pre SESS, the question about student enjoyment of learning math while playing cooperatively received positive responses from 58% of students. The item on enjoyment of whole class gameplay received positive responses from 53% of students. While the item on enjoyment of competitive gameplay received positive responses form 42% of students. Students' enjoyment preferences shifted by the end of the treatment period with a larger percentage of students that agreed or strongly agreed that they enjoy learning math while playing competitively, playing as a whole class, and playing cooperatively, respectively (Figure 1).

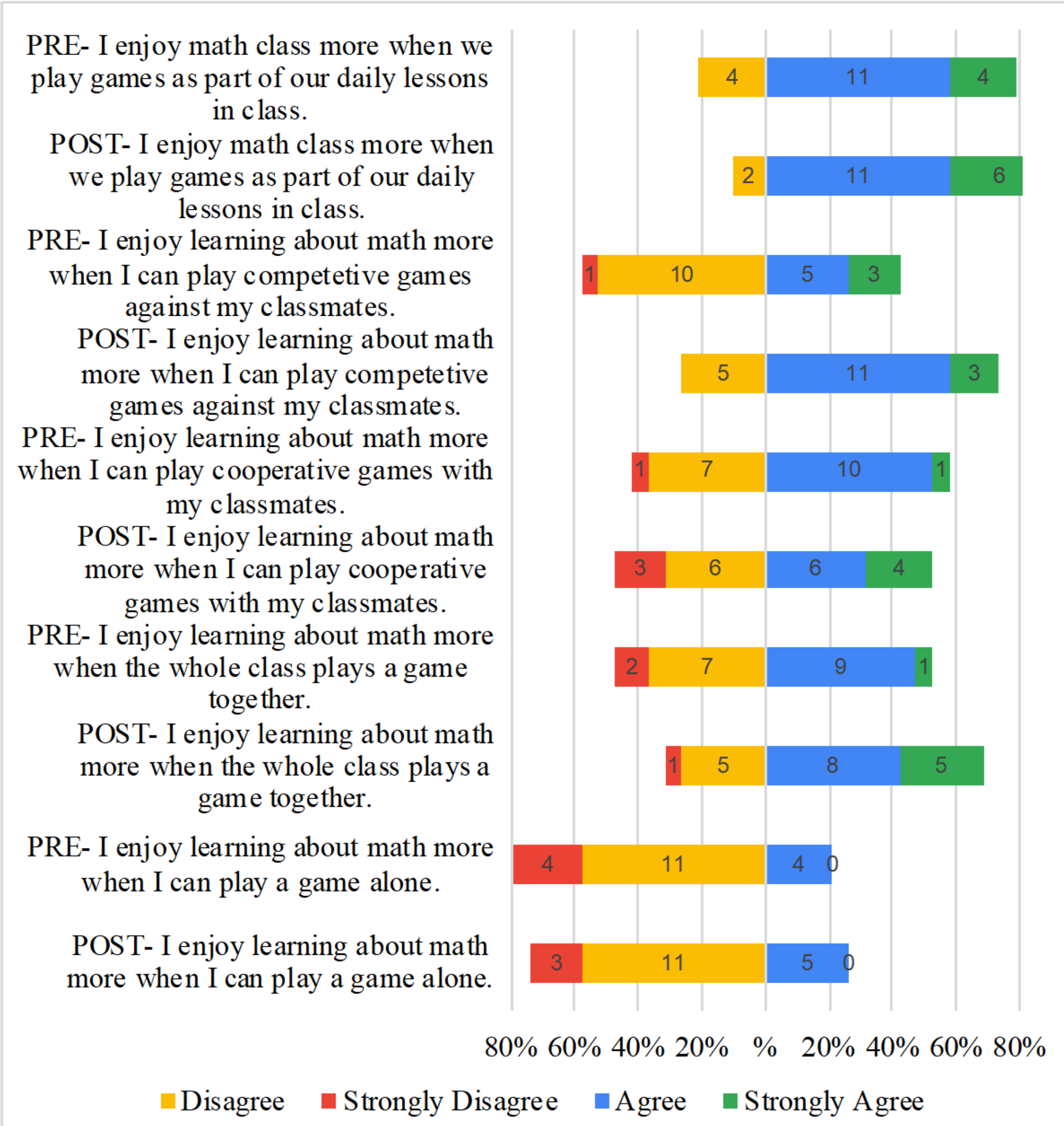

Figure 1. Student responses on SESS items about enjoyment when engaging in game-based learning of math, (*n*=19).

On the post SESS, 74% of students agreed or strongly agreed that they enjoy learning math while playing games competitively against their classmates. Sixty-eight percent of students agreed or strongly agreed that they enjoy learning math while playing games together as a whole class on the Post SESS. Similar to the pre SESS, 53% of students agreed or strongly agreed that they enjoy learning math while playing games cooperatively with classmates on the Post SESS. The number of positive responses from students on the post all Post SESS items about enjoyment, increased, with the exception of responses to cooperative gameplay. By the end of the treatment period, the proportion of students responding negatively about their general enjoyment of playing games in math class decreased to just 11% of sample population. Using the average of student responses from both the pre and post SESS to calculate normalized gains revealed low gains in student responses about their enjoyment while learning math via GBL.

Student responses on the first SESS of the treatment period regarding their sense of confidence learning math while playing games mirrored those on the enjoyment section, most students responded positively. Sixteen percent of students strongly agreed when asked if they feel more confident learning about math when we play games as part of our daily lessons in class and 63% of students agreed to this question. The remaining, 21% of students responding negatively to this SESS item about their sense of confidence learning math while playing games in class (*n*=19). On the first SESS of the treatment, students showed some preferences about their confidence learning math when engaging in a specific gameplay format. Student responses on items about their confidence learning math by playing games were most positive related to playing cooperatively, whole-class, and competitively, respectively. On the pre SESS, 74% of students gave positive responses to the item about their confidence learning math while playing games cooperatively with classmates. Fifty-eight percent of students responded positively about their confidence learning math while playing games as a whole class on the pre SESS.

The third highest number of positive responses, 47% of students, agreed or strongly agreed that they feel confident learning math while playing games competitively against classmates (Figure 2).

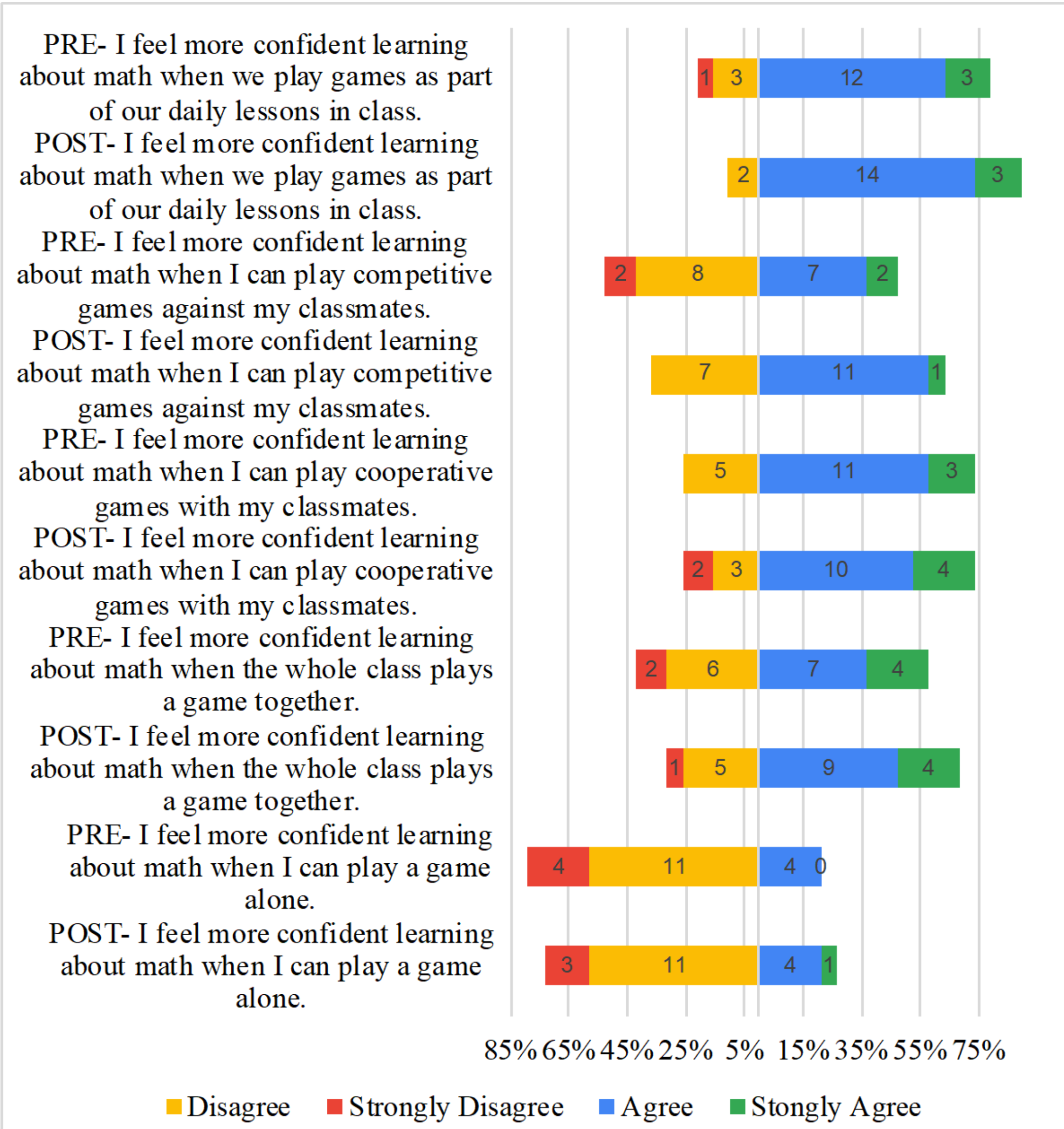

Figure 2. Student responses on SESS items about confidence when engaging in game-based learning of math, (*n*=19).

Students' sense of confidence learning math while playing games shifted by the end of the treatment with the exception of cooperative play which received the most positive responses from 74% of students on the Post SESS. Also, on the Post SESS student confidence while playing as a whole class received positive responses from 68% of students. Finally, on the Post SESS student confidence learning math while playing competitively against classmates was third highest with 63% of students that agreed or strongly agreed that they feel confident. Student responses about their enjoyment and self-confidence while playing math games alone received the most negative responses of all the gameplay formats on both the pre and post SESS. Using the average of student responses from both the pre and post SESS to calculate normalized gains revealed low gains in student responses about their confidence while learning math via GBL.

Student's scores were lower the first time completing the Mathmagic game individually as an assessment of their knowledge confidence on sixth grade math standards, than on their second attempt on the Mathmagic Answer Sheet (MAS) (*n*=19). Some students chose to complete more than the requested six math problems, with some completing the entire 15 questions included in the Mathmagic game. The knowledge confidence scores from the pre and post MAS are presented below in whisker-box plots. Using the average of student scores from both the pre and post MAS to calculate normalized gains revealed medium gains in student confidence in their knowledge of sixth grade math standards (Figure 3).

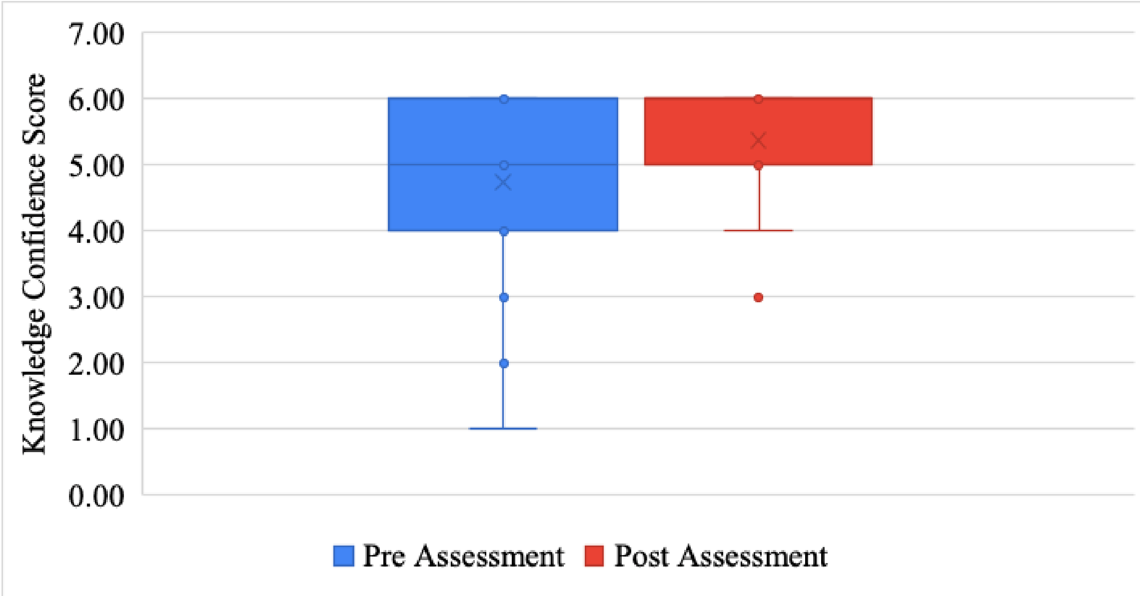

Figure 3. Individual student knowledge confidence scores from Pre and Post treatment session Mathmagic Answer Sheets, (*n*=19).

Throughout the treatment period the teacher/facilitator recorded each students' choice of gameplay format. This student choice data from four different treatment sessions was analyzed and appear to align with the SESS responses collected at the beginning and end of the treatment period with a couple of exceptions. For example, during the two treatment sessions where students were given the choice of playing competitively, cooperatively, or individually, 25% of students chose to play the game individually overall (Figure 4). This is unexpected given the generally negative responses that students gave about their enjoyment of learning math while playing games alone on the Pre and Post SESS. While these students were placed into small groups, they were each free to play the game independently.

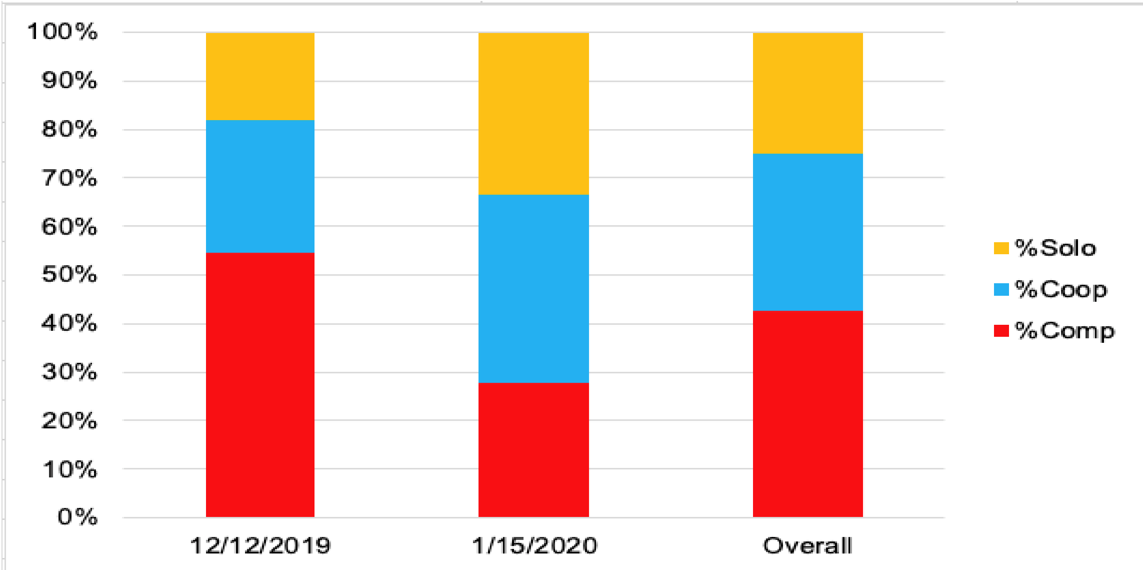

Figure 4. Student choice of gameplay format during small group play as recorded in the Teacher Journal, (*n*=19).

The number of students that chose to play competitively decreased after the first treatment session when students were asked to make a choice about their gameplay format. This was also in contrast to student responses about their enjoyment and confidence learning math while playing games on the Pre and Post SESS. During the latter two treatment sessions when students were instructed to play with a partner instead of a small group, the majority chose to play cooperatively with their playing partner (Figure 5). The general popularity of playing the game cooperatively or competitively as determined by student SESS responses was reflected in students' individual choices about their own format of engagement in the GBL treatment.

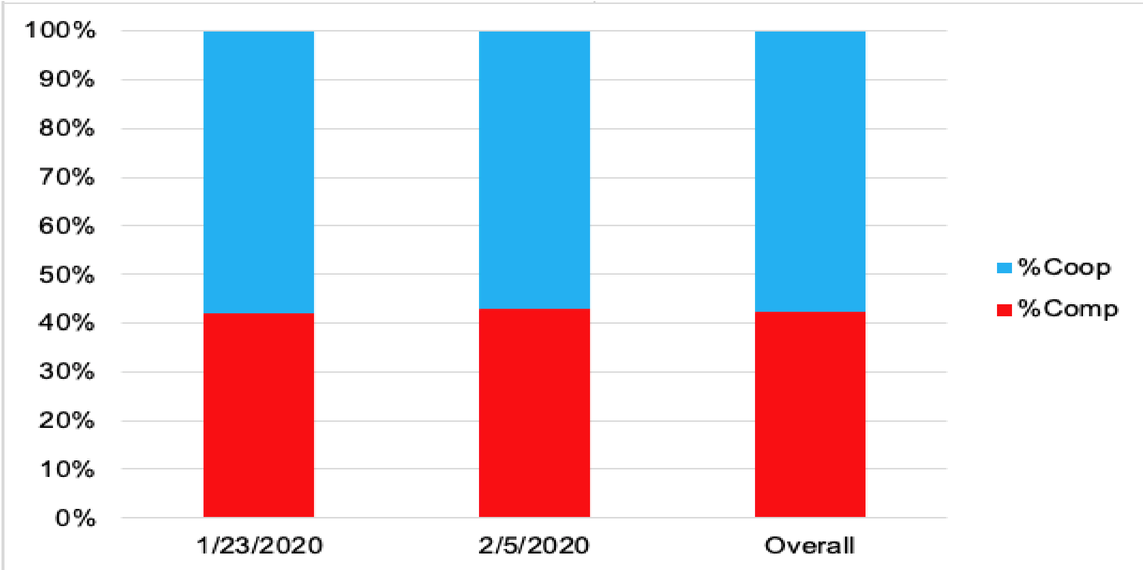

Figure 5. Student choice of gameplay format during partner play as recorded in the Teacher Journal, (*n*=19).

The Teacher Journal revealed that student focus and engagement appeared to be higher when students played the game in partners or individually than when playing as small groups. The facilitator noted that when playing in smalls groups, students playing cooperatively, or individually, appeared to be more on task than those students playing in competitive groups. In a later treatment session when students played in partners, it was noted that students were blurring the lines between competitive play and cooperative play. One pair of students shared, “We are helping each other but we are still competing.” It was also noted that a small portion of students showed signs of fatigue from having to play the same game repeatedly, despite the content in the game changing. Some students expressed their frustration by asking, “Can we play a different game today?” and, “Do we have to play this same game again?” While other students were more concerned about being able to play with their friends in class with questions such as, “Can we pick our own groups to play in?” and, “Can we play as a whole class again?” However, most student feedback throughout the treatment was positive with one student even writing a note on their Mathmagic Answer Sheet saying, “I really like this game so fun and helpful!” As stated before, on the final treatment session, when given the choice to play the game in small groups, partners, or as a whole class, the class voted almost unanimously to play the game as a whole class.

CLAIM, EVIDENCE AND REASONING

Claims for the Study

One claim which can be made from this study is, giving students choices about their mode of engagement in game-based learning (GBL) will likely improve their attitudes about their enjoyment and confidence in learning math. On the first Student Enjoyment and Self-Efficacy Survey (SESS), students reported the highest enjoyment and self-confidence playing cooperatively coming into the treatment. This was corroborated by the Teacher Journal data which showed that when given the choice between playing cooperatively or competitively students predominately chose to play cooperatively. On the second administration of the SESS, positive student responses about their enjoyment of cooperative gameplay decreased slightly from 58% to 53%, but their reported sense of confidence remained high, with 74% percent of students who agreed or strongly agreed that they feel more confident learning math while playing cooperatively. During the treatment period students reported that their sense of enjoyment and confidence increased while playing competitively. The percentage of positive responses to items about enjoying learning math while playing competitively increased from 42% to 74% of students. In addition, when it came to their confidence learning math while playing competitively the percentage of positive responses increased from 47% to 63%. While their responses on the SESS may have reflected an increase in their enjoyment and confidence playing competitively it is unclear why students were more likely to play cooperatively. This may be due to social pressures of working with other classmates and not just their personal preferences of gameplay format. In addition, a surprising number of students chose to play the game individually when given the option. This was in stark contrast to the Student responses on the pre and post SESS, which revealed that students had the most negative responses about their enjoyment and confidence learning math while playing games alone. I believe this may be due to biases and stigma surrounding individual gameplay which can be perceived as individuals having to play alone or being anti-social. Student attitudes toward playing games as a whole class improved in terms of both enjoyment and self-confidence. Student responses about their confidence playing games increased during the treatment on all SESS items, except for cooperative gameplay. Whole class format of play seemed very enjoyable to the majority of students and because of the social pressures of team play even the least engaged students were forced to cooperate with their teammates. These results suggest that designing game-based learning math lessons in which students can choose to engage cooperatively or competitively with each other, could increase their enjoyment and confidence during math lessons. However, these two formats of gameplay should not be considered the only viable forms of GBL engagement, and engaging with classmates in gameplay should not be compulsory.

This research also suggests that providing students with a gamified version of a performance assessment could increase their levels of engagement and effort. On the two separate occasions during the treatment when students were asked to complete at least six problems from the Mathmagic game and record their answers on the Mathmagic Answer Sheet (MAS), student confidence in their math knowledge was relatively high. During the second treatment session when students were asked to record their answers on the MAS, the average student confidence in their math knowledge score increased. This increase was considered to be medium gains when using average scores to calculate normalized gains. This may be in part due to gains in math skills and knowledge, however it may also be due to student familiarity with the Mathmagic game format. Clearly, students attempted more questions on their second final attempt on the MAS compared their initial attempt.

Value of the Study and Consideration for Future Research

Results from the SESS suggests that there are some compounding factors when it comes to students' attitudes about gameplay format and their actual choices of engagement. For instance, SESS items on individual gameplay received the most negative responses of all the gameplay formats. However, when given the choice during treatment sessions nearly one third of students chose to play the Mathmagic game alone. These inconsistencies suggest that this interplay between attitudes and personal choices deserve further investigation in terms of GBL game design.

Additionally, gamification of performance assessments could be a valuable field for further research and development. The results of this study suggest that the gamification of formative assessments could lead to an increased level of engagement and effort from students. In addition, the results from this study suggest that student comfort and familiarity with a particular game or style of gameplay could relieve or reduce testing anxiety and malaise. Given the motivating and sometime addictive nature of video games and the recent digitization of standardized testing platforms, gamification of performance assessments deserves further investigation. Many video games are nothing more than a series of skill assessments or knowledge assessments that the player must perform well on in order to progress in their gameplay.

Impact of Action Research on the Author

This action research project has given me a greater understanding of the value that GBL has in the math classroom. This study demonstrated to me GBL's usefulness not only as a tool for instruction and practice, but also as a tool for assessment. The process of creating this action research study allowed me to step into the role of a regular classroom teacher to both design treatment lessons and also design data collection instruments. Creating this action research treatment, with very specific objectives in mind, will give me a foundation of experience when creating new standards-focused lessons and assessments. The experience that I gained from creating my own data collection instruments will be invaluable during my career in education and allow me to effectively utilize data from my own classroom to improve my own teaching methods in order to better facilitate student learning and achievement. I also experienced some frustrations when trying to design data instruments given my inexperience with creating Likert type surveys.

One major impact on me as a teacher was the level of enthusiasm that most students demonstrated when allowed to engage with their peers in the GBL treatment. Of course, there were exceptions to this trend, some students were definitely hesitant to engage with classmates competitively or cooperatively. However, observations recorded in the Teacher's Journal showed that even the students who chose to engage individually with the Mathmagic game, were quick to partner up "unofficially" with another classmate who also chose to play individually. In addition, student enthusiasm for playing the game as an entire class with students broken into several small teams was extremely high, with multiple students during nearly every treatment period asking to "play the game as a whole class again".

Another trend that was concerning to me was the small number of students that lost interest in playing the Mathmagic multiple times. While I did anticipate students experiencing some fatigue associated with playing the same game repeatedly, I was surprised at how quickly a few students lost interest. More than one student in the treatment group commented that they wanted to play a different game rather than play the Mathmagic game again. Compounding this concerning trend was the observation that most of the students who quickly lost interest were also those identified as having the lowest skills or the worst behavior issues. As an educator, I interpret this as reason to differentiate my lessons whether or not they incorporate GBL to maximize enjoyment and confidence in all of my students. While there may be some motivational benefit to continually introducing new forms of GBL such as different games or puzzles, I do feel there is also value in the familiarity which comes from repeated gameplay.

There were a few aspects of my action research which did not go as planned. For example, I had planned to collect random student interviews at the beginning and end of the treatment period. This did not occur due to the unforeseen impact of the novel Covid-19 virus. In addition, I did not anticipate some of the difficulties and complications associated with designing a treatment which was reliant upon technology. There were a few technical problems which had minor impacts on the student experience or the quality of the data collected, such as; incorrect web addresses being entered, to simply not having access to enough individual chrome books. While these are challenges that any teacher may face during an average day, they seemed to be extraordinary in terms of a control experiment setting. However, in the end the experience of creating and completing this action research study gave me first-hand knowledge and a multitude of experiences to improve my utilization of GBL in my future math and science classrooms.

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APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD EXEMPTION

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

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MEMORANDUM

TO: Hernando Oswald Velez and John Graves

FROM: Mark Quinn Mark Quinn CTJ
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: November 21, 2019

RE: *"Improving Student Attitudes about Math Using Game-Based Learning" [HOV112119-EX]*

The above research, described in your submission of November 20, 2019, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

_X_ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

_X_ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation; and (iii) the information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by section 16.111(a)(7).

___ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

___ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

___ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

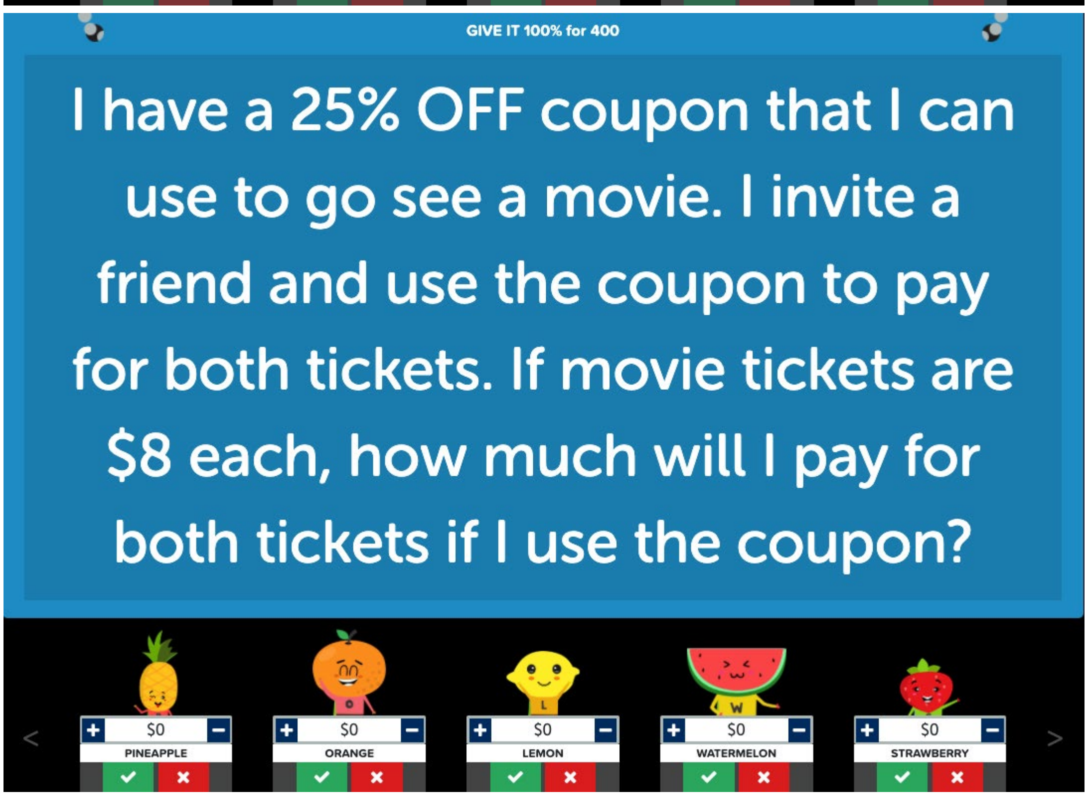
___ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

MATHMAGIC SCREENSHOTS


Mathmagic
CHECK YOUR HEART RATE
GIVE IT 100%
RATIOS ROCK
$100
$100
$100
$200
$200
$200
$300
$300
$300
$400
$400
$400
$500
$500
$500
$0
PINEAPPLE
$0
ORANGE
$0
LEMON
$0
WATERMELON
$0
STRAWBERRY


GIVE IT 100% for 400
I have a 25% OFF coupon that I can use to go see a movie. I invite a friend and use the coupon to pay for both tickets. If movie tickets are $8 each, how much will I pay for both tickets if I use the coupon?
$0
PINEAPPLE
$0
ORANGE
$0
LEMON
$0
WATERMELON
$0
STRAWBERRY

APPENDIX C

STUDENT ENJOYMENT AND SELF EFFICACY SURVEY (SESS)

GBL ENJOYMENT SURVEY

This survey is voluntary. ID #_____________

SA=Strongly Agree A=Agree D=Disagree SD=Strongly Disagree

I enjoy math class more when we play games as part of our daily lessons in class.

SA A D SD

I enjoy math class more when we don't play any games as part of our lessons in class.

SA A D SD

I enjoy learning about math more when I can play a game alone.

SA A D SD

I enjoy learning about math more when I can play competitive games against my classmates.

SA A D SD

I enjoy learning about math more when I can play cooperative games with my classmates.

SA A D SD

I enjoy learning about math more when I can watch my classmates playing games.

SA A D SD

I enjoy learning about math more when the whole class plays a game together.

SA A D S

GBL SELF-EFFICACY SURVEY

This survey is voluntary.

SA=Strongly Agree A=Agree D=Disagree SD=Strongly Disagree

I feel more confident learning about math when we play games as part of our daily lessons in class.

SA A D SD

I feel more confident learning about math when we don’t play games as part of our daily lessons in class.

SA A D SD

I feel more confident learning about math when I can play a game alone.

SA A D SD

I feel more confident learning about math when I can play competitive games against my classmates.

SA A D SD

I feel more confident learning about math when I can play cooperative games with my classmates.

SA A D SD

I feel more confident learning about math when I can watch my classmates playing games.

SA A D SD

I feel more confident learning about math when the whole class plays a game together.

SA A D SD

APPENDIX D

MATHMAGIC ANSWER SHEET (MAS)

MATHMAGIC ANSWER SHEET

ID #

Try to answer two questions from each category (6 problems)

Check Your Heart Rate	Give It 100%	Ratios Rock
100	100	100
200	200	200
300	300	300
400	400	400
500	500	500

APPENDIX E

TEACHER JOURNAL

GBL Teacher's Journal

Session Date:

Total Number of Students ________________________

Competitive ______________________

Cooperative ______________________

Individual _______________________

Percentages

% Competitive _______________________

% Cooperative ________________________

% Individual _________________________

Teacher Observations: