Final Report

Evaluation of the DimensionM Game Series in the Middle School Mathematics Classroom

prepared for

Tabula Digita, Educational Gaming Company

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Executive Summary

This white paper documents and evaluates an initiative to integrate the DimensionM educational game series into a formal educational setting. The purpose of this evaluation program was three-fold: 1) to investigate the effects of playing DimensionM on students' mathematics performance and attitudes in the context of a formal K-12 setting, 2) to evaluate students' perceptions of the DimensionM product, and 3) to disseminate the recommendations of teachers who have integrated DimensionM into a formal K-12 setting. To that end, the evaluation program employed a mixed-method approach involving both quantitative and qualitative procedures used concurrently and independently.

Two hundred twenty-five middle school students, 10 middle school mathematics teachers, and two computer resource teachers from four different Title 1 schools in two different counties in southeastern North Carolina participated in the evaluation from start to finish. Students participated in a quasi-experimental pre-test and post-test design with 16-weeks of the game intervention. Teachers were provided flexibility in choosing how to integrate DimensionM into their classrooms with a minimum requirement of one session (average length of 69 minutes) of DimensionM play per week. The evaluation examined students' attitudes towards mathematics, mathematics self-efficacy, and mathematics achievement before and after the intervention. Mathematics achievement was measured by a student's performance on a low-stakes assessment linked to North Carolina middle grades standards. The students' gender, socio-economic status (SES), ethnicity, frequency of game play, and frequency of computer use were examined as moderating variables and covariates.

All teachers participated in an interview using the semi-structured interview protocol with at least two members of the evaluation team. The interviews lasted approximately 45 to 60 minutes each, and were recorded for later transcription. After, teachers attended a focus group with the purpose of presenting the preliminary results of interviews, using the results to stimulate discussions, confirming the results with each of the teachers, and identifying any missing relevant information.

Student data were analyzed using both descriptive and inferential statistical procedures. Analysis of Covariance (ANACOVA) detected significant and positive changes in students' attitudes towards mathematics and mathematics self-efficacy. Overall, mathematics achievement scores increased from pre-test to post-test. However, the change was not statistically significant. A students' gender, SES, and frequency of computer use did not significantly interact with any of the criterion measures. Students' evaluation of DimensionM was positive: more than 90% indicated that some or most of the activities were fun; approximately 67% felt the activities were just right in their level of complexity, and about 89% believed DimensionM allowed them to demonstrate some or most of their mathematics skills and knowledge.

These findings are prefaced with limitations with the evaluation. The design was quasi-experimental in that it did not involve a comparable control group receiving an alternative treatment and random assignment. The validity and the reliability of the evaluations are limited by the honesty of the student participants' responses to the instruments used. Also, some of the measures employed in this evaluation lacked strong internal consistency reliability (< .7) and the only form of control for a test effect was the scrambling of items and distracters from pre-test to post-test. Finally, using the status of whether a student is on free or reduced lunch as the only proxy for SES may not accurately represent this population.

The interview and focus group data were analyzed using a constant comparative qualitative procedure. The findings provide compelling evidence that the use of modern educational games in a formal K-12 setting serves as an agent for change in instructional practice, student-to-student and teacher-to-student relationships, the skills and dispositions of students. Several curriculum integration strategies were reported by participating teachers, including the use of a modern educational game as a reward system, for concept reinforcement, for differentiated instruction, and more. Teachers reported several changes in student interactions, including mentoring and tutoring each other, a willingness of students to seek help when needed, socialization across social “groups”, and simultaneous competing and cooperation during game play. Teachers also noted several 21st century skills, including problem-solving, collaborating and cooperating, leadership, and technological skills.

We preface these changes with two antecedents: professional development and support for teachers. Teachers were provided access to two workshops tailored specifically for integrating the DimensionM game into their classrooms. Teachers need access to programming that will prepare them for the many complexities in a gaming classroom. Further, teachers in this program were provided with support not only from their computer-resource teachers, but also from district, company and evaluation team personnel. These two key ingredients for teachers are necessary for successful game integration initiatives.

A discussion and several recommendations to educators, educational researchers, and game designers are provided for future initiatives. The recommendations are summarized here.

To **educational game designers**, we recommend:

1. Provide educators access to a support line to seek assistance during regular school hours.
2. Assure all games be tested on machines that are located in schools prior to adoption.
3. Provide teachers with a clearly written set of game instructions, tutorials or handouts on how to play the game, suggestions on ways to integrate the game into the classroom, and caveats on integration.
4. Provide a reporting utility that is detailed, current, and flexible. That is, the data should update on a regular basis and should provide teacher many different ways of viewing the information (e.g., graphs, detail reports).
5. Provide teachers and students information regarding how points and designations are earned needs within the product.
6. Structure the single player games so that they can be saved mid-mission or have different points along the way where the mission can be stopped and returned to at a later date.
7. Provide materials for the parents that highlight ways that they can interact with their child while using the game and highlight the effects of the game on student learning.

To **educators**, we recommend the following:

8. Spend the necessary time to learn about the game.

9. Create a clear implementation plan or strategy that aligns with curriculum standards and instruction prior to introducing the game into the classroom.
10. Shift to a student-centered environment and allow student leaders to emerge.
11. Administrators should be supportive of teachers that are willing to try modern educational games in their classrooms.
12. Do not be threatened or scared by modern educational games. Welcome the changes in your classroom.
13. Implement with your peers to assure you have someone to consult with and to share ideas with.

To **educational researchers**, we recommend the following:

14. We need more researchers to spearhead this complicated domain in contexts that can be replicated by others.
15. Use the game technology to record user interactions to represent different types of measurements ranging from achievement data (e.g., accuracy) to timing data (e.g., speed) to behavioral data (e.g., on-task).
16. Examine the influence of educational game play on mathematics achievement longitudinally, taking several measurements at different points in a students' development.
17. Focus more heavily on the design of games and how they are integrated into the classroom when accounting for effects on learning.
18. Use the qualitative findings for further research to confirm the observations made by teachers using different methodologies.

Introduction and Purpose

The use of modern educational games in formal K-12 settings is at a tipping point. The research shows that 97% of teenagers are playing video games, and that gamers devote more than three times the amount of time playing video games than any other activities (Pew Research, 2008). What if teenagers were spending even a fraction of this time studying? Game developers (Aldrich, 2004; Prensky, 2001; Tabula Digita, 2009) and educational researchers (Gee, 2003; Rieber, 1996; Squire, 2003) have begun to focus their attention on how to engage students in educational gaming environments with rich and interactive content that closely resembles the high-end, modern games they play on their Xbox 360 or PlayStation. Consequently, we now have educational gaming conferences (e.g., Games + Learning + Society - http://glsconference.org/), educational gaming journals (e.g., *International Journal of Gaming and Computer-Mediated Simulations*), and several new educational video game companies that use the powerful technology to harness the interest of students (e.g., Muzzy Lane or Tabula Digita).

Gee (2007) asserts that for games to be effective in formal education, game designers, scholars, and educators need be in full accord as to how games would best be integrated into the classroom. Developers, educators and scholars are drawn to the notion of educational games because they are believed to be effective and efficient tools for delivering complex subject-matter. They "(a) use action instead of explanation, (b) create personal motivation and satisfaction, (c) accommodate various learning styles and skills, (d) reinforce mastery, (e) provide interactive, decision-making context" (Kebritchi, 2008, p. 15), and (f) can promote collaboration among learners (Kaptelin &

Cole, 2002). Yet, meta-analytic studies on the use of educational games (Dempsey, Rasmussen, & Lucassen, 1996; Vogel, Vogel, Cannon-Bowers, Bowers, Muse, & Wright, 2006) suggest a wide disconnect between learning and the use of games in a formal educational setting. Ke (2008) notes that "common skepticism on using computer games for learning purposes lies in the lack of an empirically-grounded framework for integrating computer game into classrooms" (p. 1609). This lack of empirical research is especially true in the use of educational games in mathematics (Kebritchi, 2008).

Squire (2003b) remarks that integrating modern educational games into formal K-12 settings potentially raises as many problems as it solves. Educational games may not appeal to every student equally (e.g., gender) (Ke, 2008) and students may be distracted by game-playing, and consequently, not achieve the educational goals (Miller, Lehman, & Koedinger, 1999). There are numerous barriers to successfully integrate games; including scheduling, setting, class expectations, teacher background, genre knowledge, technical problems, teacher preparation, perception of games, class size, and priority issues – all of which place a tremendous burden on teachers (Egenfeldt-Nielsen, 2004). Further, game designers (Smith & Mann, 2002) fear that integrating modern games into formal educational settings with the sole objective of influencing students' learning will forgo the "fun" part of the game, ergo, diminishing students desire to play. All of these complications re-iterate the importance of the assertion raised by Gee (2007) and underscore the need to further evaluate educational games in formal K-12 settings.

Therefore, the purpose of this evaluation program is three-fold: 1) to investigate the effects of educational game play on students' mathematics performance in the context of a formal K-12 setting, 2) to evaluate these students' perceptions of the educational game product, and 3) to disseminate the recommendations of teachers who have integrated a modern educational game into a formal K-12 mathematics classroom. To address the first and second purpose, the effects of playing DimensionM (see *Game Intervention*) on middle school students' attitudes towards mathematics, mathematics self-efficacy, and mathematics achievement was investigated using a quasi-experimental design. At the completion of the intervention, students were provided an opportunity to evaluate the product. The third purpose was addressed by interviewing participating teachers, followed by a focus group session. This type of discourse, in distinction, sheds light on the practical implications of integrating educational games into the classroom by highlighting the challenges, lessons learned, exemplary practices, and insights of experienced K-12 teachers.

Relevant Literature

The relevant literature reported here addresses the effects of educational games in mathematics education and teacher discourse on educational games.

Effects of Educational Games in Mathematics Education

Previous educational research on the influence of modern educational game play on mathematics education is limited and has produced mixed results. The literature presented here purposefully includes only peer-reviewed research on educational game play in mathematics published after 2000 in chronological order. The characteristics of the various studies are illustrated in Table 1.

Table 1. *Previous peer-reviewed research on game play in mathematics.*

Researchers/Year	**N**	**School Level**	**Dependent Vars.**	**Independent Vars.**	**Outcome**
Rosas et. al., 2003	1,274	Elementary	Math achievement, Motivation, On-task behavior	Game usage	Positive
Laffery et. al., 2003	56	Elementary	Math achievement, Behaviors	Game usage, Risk factor	Positive
Ke & Grabowski, 2007	125	Elementary	Math achievement, Math attitudes	Goal structure, SES, Gender	Mixed
Lopez-Morteo & López, 2007	77	High School	Math attitudes	Game usage	Positive
Kebritchi, 2008	193	High School	Math achievement, Motivation	Game usage, Computer experience, Language	Mixed
Ke, 2008	15	Elementary	Math achievement, Metacognitive awareness, Math attitudes	Game usage	Mixed

Rosas, Nussbaum, Cumsille, Marianov, Correa, Flores, Grau, Lagos, López, López, Rodriguez and Salinas (2003) studied the effects of integrating instructional video games in a classroom setting on mathematics achievement, motivation, and on-task behavior. Their study involved 1,274 students from economically disadvantaged schools in South America over a 3-month period with a minimum of 30 hours of game play by each student. Their results suggest positive effects on mathematics achievement, students' motivation to learn using games, and the frequency of on-task behavior observed during class time.

Laffery, Espinsosa, Moore and Lodree (2003) conducted an experimental study comparing the performance of young, urban, African-American children from low-SES backgrounds (N=56) who were given specially selected computer supported gaming experiences in mathematics with a comparison group who did not receive the treatment. Specifically, the researchers examined the influence of the eight-week treatment on mathematics achievement and behavior (e.g., attention, enthusiasm, and engagement). Their results suggest positive influence on behaviors and mathematics achievement.

Ke and Grabowski (2007) conducted an experimental study involving 125 fifth-grade students in the northeast United States (US) over a four-week period. This study focused on different goal structures in computer game play and the influence on mathematics' measures. Thus, the independent variable was the goal structure (cooperative game play, competitive game play, and a control group); and the dependent measures included mathematics achievement and attitudes towards mathematics. Their results indicated that game playing was more effective than the control group in influencing mathematics achievement, and that cooperative game playing was most effective for promoting positive attitudes towards mathematics.

Lopez-Morteo and López (2007) evaluated the implementation of an interactive, computer-supported learning environment that emphasized multiplayer mathematics games. The study investigated high school student (*N*=77) attitudes towards mathematics as a result of using the interactive environment. They concluded the use of the system positively impacted student attitudes towards mathematics and that more research was necessary.

Kebritchi (2008) conducted an experimental study with 193 students from ten urban high schools in the southeastern US over an 18-week period. The study employed a 3D immersive mathematics game called DimensionM and examined the effects of game play on mathematics achievement and motivation. The results indicated significant improvement of the mathematics achievement when comparing the experimental (those that played games) versus control group (those that did not). Overall, no significant improvement was detected on motivation when comparing groups. However, a significant improvement was detected on motivation of the participants who played the games in their school lab and classrooms compared to the ones who played the games only in the school labs.

Ke (2008) examined the effects of five-weeks of computer game play on fourth and fifth graders' math achievement, metacognitive awareness, and attitudes toward learning mathematics. The game intervention was a series of web-based drill and practice games developed in Flash. The study employed a mixed methods approach with 15 elementary school students. Results indicated that participants developed more positive attitudes toward math learning through game play; however, there was no significant effect on students' mathematics achievement or metacognitive awareness development.

There are few consistent findings across these studies. Some suggest positive influences on mathematics performance while others only suggest influences on affective measures (e.g., motivation) or behavioral measures (e.g., on-task behavior), or all the above. Further, the studies vary on several pertinent factors; including, the type of game employed (e.g., immersive 3D games, web-based), the duration (e.g., five-weeks) of the intervention, the frequency (e.g., one time per week) of the intervention, the dependent measures examined (e.g., attitudes towards mathematics), the methodology employed (e.g., experimental), the grade level of the participants (e.g., elementary school), the educational setting (e.g., computer lab), and the population under investigation (e.g., South American).

To add to the complexity, there is little to no consensus on which individual differences potentially confound the results. Individual differences that have been examined include computer experience (Ke & Grabowski, 2007; Kebritchi, 2008; Lopez-Moreto & Lopez, 2007), prior knowledge (Ke & Grabowski, 2007; Kebritchi, 2008), socio-economic status (Ke & Grabowski, 2007), and gender (Ke & Grabowski, 2007). The current body of knowledge on the effects of game play on mathematics performance demonstrates a clear need for more research in order to generalize research findings.

Teacher Discourse on Educational Games

To date, some research has attempted to capture teacher discourse. Can and Cagiltay (2006) examined Turkish pre-service teacher (N = 116) perspectives of using games with educational features in their future practice. Their results suggest pre-service teachers have positive perceptions regarding the use of computer games and plan to use games in their future professions. Their findings also show skepticism, especially concerning the issues of classroom management and the educational effectiveness of computer games.

Future Lab, a non-profit organization for innovation in teaching, conducted a survey of primary and secondary teachers (*N* = 1,000) attitudes towards modern educational games in education in (Future Lab, 2005). Their findings suggest that 72% of the teachers do not play video games in their leisure time and 69% have not used games in their classrooms for educational purposes. Though 59% of the teachers would consider using games in their classroom, 49% of same population see the largest integration barrier as access to equipment (Future Lab, 2005).

Gibson, Halverson and Riedel (2007) conducted another study (*N* = 228) on pre-service teachers to examine differences in those classified as gamers and non-gamers. Their findings provide evidence of key differences in the values and attitudes held between these two categories of educators. In particular, they report that gamer teachers vary in their preferred teaching methods, value active learning more than their counterparts, and value individualized and customized teaching experiences. They also identified strong relationships between teacher play before college and game play during and after.

Niederhauser and Stoddart (2001) conducted a large-scale survey study involving total of (*N* = 1,093) in-service elementary school teachers in the mid-western US. This study was not specifically about computer games, but rather about a broad range of educational software that included two orientations: open-ended (constructivist orientation, e.g., Oregon Trail) and skill-based (positivist orientation, e.g., MathBlaster). The results show teachers' students were using skill-based software alone or in combination with open-ended software in the majority of classrooms. Their findings also show a strong connection between teachers' pedagogical philosophies and the types of educational software teachers report using with their students.

Two of the four studies noted only examined pre-service teachers' perceptions and attitudes (Can & Cagiltay, 2006; Gibson, Halverson, & Riedel, 2007). Though this information is valuable, pre-service teachers are not currently practicing and have likely not attempted to integrate modern educational games into their classrooms. In one study, the focus was not on educational games and did not attempt to garner the experiences of these teachers to inform future practice (Niederhauser & Stoddart, 2001). In the other study, the results confirmed that the majority of the teachers were not gamers (72%) and had not integrated games into their classrooms (69%) (Future Lab, 2005). The body of literature involving the teachers' voices on the integration of modern educational games in the K-12 classroom is largely deficient.

Method

Participants

Student participants: Four hundred ninety-seven middle school students from four different Title I schools in two different counties in southeastern North Carolina participated in the evaluation program. Of the participating students, 225 of these students (45%) completed the evaluation program, which included a pre-test, post-test and a 16-week intervention (see *Procedures*). Fifty-one percent of the participants were female. Of the ethnicity of the participants, 48% were classified as White, 35% were Black, 11% were Hispanic, and the remaining classified as Asian or Other. Sixty-four percent of the student participants were enrolled in the free or reduced lunch program, which serves as a proxy for socio-economic status (SES). Students that participated in the program are identified as economically disadvantaged and normal. Ninety-six percent of the student participants indicated English as their primary language. Student participants represented all grade levels in middle school, including 41% in eighth grade students, 36% seventh grade, and the remaining in sixth grade. Seventy-two percent of the participants reported using computers for more than five years, and the remaining from one to five years.

Teacher participants: Ten middle school mathematics teachers and two computer resource teachers from the four schools participated in the evaluation program. The teachers ranged in K-12 teaching experience from two to 40 years with an average of M = 11.83 (SD = 13.24) years and with an average of M = 6.13 (SD = 4.79) years of K-12 teaching experience with computers. Two of the teachers were male and the remaining female. All of the teachers involved in the program reported no previous experience with integrating complex, modern educational games into their curriculum. The ten mathematics teachers taught general pre-algebra courses with sixth, seventh and eighth grade students. The computer resource teachers assisted teachers with curriculum and technology integration. Only three of the teachers involved in the program reported playing video games in their leisure time. One of the computer resource teachers was not involved in any of the curricular decisions, and thus, was removed from the analysis.

Game Intervention

DimensionM, is a modern educational game series that engages students in the learning of Pre-Algebra and Algebra concepts in a 3-D immersive game environment (DimensionM, 2009). A screen shot of the game is provided in Figure 1. The game series, which was used as the treatment in this evaluation program, currently includes three components:

1. *Evolver Multiplayer*: The game reinforces Pre-Algebra and Algebra concepts by involving multiple players in three different competitive scenarios requiring both speed and accuracy in solving mathematics problems. Multiplayer games can be played in short intervals, such as five, 10, 15 or 20 minutes sessions.
2. *Evolver Single Player*: This game instructs Pre-Algebra concepts by involving players in completing 20 mathematics missions within a 3-D immersive environment. The missions also included web-based Flash instructional modules that could be traversed by students individually or used by the teacher.
3. *Dimenxian Single Player*: This game teaches Algebra concepts by engaging players in four mathematics missions within a 3-D immersive environment.

Figure 1. *Example screen-shot of DimensionM game.*

The 10 mathematics teachers were given flexibility in choosing how to integrate the DimensionM into their classrooms. The research program only required that their students play the DimensionM games series once a week for a full class session over a 16-week period. All teachers reported a one-to-one computer to student configuration during game time. Game play occurred in both computer lab and classroom settings. The sessions lasted an average of 69.27 minutes (*SD*=15.68). In terms of usage, teachers reported using the single player missions (Evolver Single Player and Dimenxian Single Player) most frequently followed by the multiplayer game (Evolver Multiplayer). The instructional modules (Evolver Single Player) were used least.

Measurements

The evaluation program involved several different measurements. The measurements are all composites based on previous research. Internal consistency reliability measures are provided (Cronbach's alpha and K-R 20), and is evaluated using the social science standard of values greater than or equal to .70 (Nunnaly, 1978). Any negatively stated items were reversed coded for analysis purposes. The items are available for review in Appendices B to G.

Frequency of computer use: The frequency of computer use measure is derived from the Programme for International Student Assessment (PISA), which has been rigorously analyzed to demonstrate both reliability and validity across diverse international populations (PISA, 2003; Hohlfeld, Ritzhaupt, Barron, & Kemker, 2009). The assessment included 10-items measuring the extent to which technology (e.g., The Internet to download software, music, or files.) is used on a 5-point scale (Never, Less than once a month, Between once a week and once a month, A few times each week, and Almost every day). The scale demonstrates an acceptable level of internal consistency reliability for these data at $\alpha = .80$.

Frequency of game play: The frequency of game play measure is also derived from previous research (Ritzhaupt, 2009). The scale uses 9-items to measure the frequency to which individuals play various game genres (e.g., sports games or role-playing games) using the 5-point scale (Never, Less than once a month, Between once a week and once a month, A few times each week, and Almost every day). The scale demonstrate a high level of internal consistency reliability for these data at $\alpha = .87$.

Attitudes towards mathematics: The attitudes towards mathematics measure includes 11-items targeted at gauging an individual's perception of the discipline of mathematics. The scale is derived from previous research (Murphy, 2007) and uses a 4-point scale (Strongly disagree, Disagree, Agree, and Strongly agree). For example, one item reads "Mathematics is an important field of study." Thus, the scale attempts to measure student feelings, such as love, hate, anxiety, interest, and a perception of the utility of mathematics to everyday life. The internal consistency reliability of the scale is relatively low with Cronbach's alphas at α =.52 and α =.57 for the pre-assessment and post-assessment, respectively.

Mathematics self-efficacy: The math self-efficacy measure is based on previous research (Murphy, 2007) and uses the 4-point scale (Strongly disagree, Disagree, Agree, and Strongly agree) to measure the extent to which an individual believes him or herself is capable of performing mathematics in an academic setting. For instance, one item states "Solving math problems is easy for me." The scale has varying internal consistency reliability from pre-test to post-test at α =.51 and α =.65, respectively.

Mathematics achievement: The mathematics achievement measure is drawn from the North Carolina Standards Course of Study for Middle Grades (sixth-eighth) mathematics. Thirty-five items were carefully traced to five competency goals, which included number and operations, measurement, geometry, data analysis and probability, and algebra. The items were scored dichotomously, and thus, the measure ranges from zero to 35. The scale has near acceptable internal consistency reliability for these data from pre-test to post-test at K-R 20 =.61 and K-R 20 =.65, respectively. Note the items and distracters were purposefully scrambled from pre-test to post-test to control for a testing effect. The mathematics achievement assessment did not count towards students' final grades in their courses, nor was it a formal high-stakes assessment used for promotion and retention.

Teacher Interview Protocol

Members of the evaluation team conducted an extensive review of current research on modern educational games integrated into formal K-12 settings. This literature served to inform the design of a semi-structured interview protocol with 30 different questions. All of the questions were purposefully open-ended to gain further insight into the teacher experiences of the game integration initiative. The interview protocol addressed the following germane areas: teacher experience and background, technology infrastructure and support, session and usage details, curriculum integration information, challenges, lessons learned, student observation information, and general evaluation insights. The protocol is presented in Appendix A.

Procedures

In September of 2008, teachers in 11 southeastern counties in the US were sent an electronic invitation to attend a workshop hosted by a regional university on integrating modern educational mathematics games into the classroom. The invitation stated that select teachers in attendance would be invited to participate in an evaluation program the following semester. Approximately 25 teachers, administrators and other school district personnel attended the three-hour workshop and 15 teachers completed a short survey relating to prior experience with technology, school and district criteria, and school technology capacity.

Ten teachers were selected to participate in the program from four different schools in two different counties (based on school capacity and experience). To assure commitment, participating teachers were offered a $200 stipend for their participation. In January of 2009, participating teachers were required to attend a workshop that explained the evaluation protocol, demonstrated how to integrate DimensionM into the classroom (teachers were provided a curriculum map of the standards in DimensionM), and outlined the procedures for installation and configuration of the product within the schools.

The procedures for the evaluation program are illustrated in Figure 2. All student data was collected online and assessments were administered by teachers in a controlled lab environment during one class session. Each student was assigned a unique number by the teachers, which was used from pre-test to post-test to link the students. This assured the anonymity of the student participants in that only the teachers knew their true identities. The pre-test collected basic student demographics (e.g., gender or SES), frequency of computer use, frequency of game play, and the three criterion measures, attitudes towards mathematics, mathematics self-efficacy, and mathematics achievement. The post-test included the same three criterion measures and a short survey designed to evaluate the DimensionM product from a student perspective.

Figure 2. *Evaluation program procedures.*

The evaluation program required one session of play a week for all student participants. To assure adequate progress, bi-weekly emails were sent to participating teachers to ascertain information and offer any support. The evaluators made scheduled site visits to each of the schools on two occasions to observe students during game play and to gather intermittent information from teachers. Teachers were provided technical support in several ways: 1) from school computer resource teachers, 2) district technical support staff, 3) from the Tabula Digita support staff, and 4) from the evaluator team.

To encourage students to take the evaluation program seriously, the student that scored the overall highest score playing DimensionM across the four schools was awarded a Nintendo DSi, and the school that had cumulated the highest weighted average score received a pizza party. The DimensionM game series tracks student progress for reporting purposes. This information was shared with the students upon starting the evaluation program. Student participants had to successfully complete all aspects of the evaluation program to be included in the data analysis. Student participants that did not participate in the full 16-week intervention (e.g., moved into class later in term) or complete at least 75% of the pre-test or post-test (e.g., were not in attendance during testing) were dropped from the analysis. This attrition resulted in a final data set of N=225 participants of 497 that were involved in the program.

All participating teachers participated in an interview using the semi-structured interview protocol with at least two members of the evaluator team. The audio from the interviews was recorded and the members of the evaluator team also took notes during the interviews. The interviews lasted approximately 45 to 60 minutes each and were conducted in the last three-weeks of the evaluation program. After the interviews, the notes were combined by members of the evaluator team and the audio from the interviews was transcribed into individual documents for each teacher.

At the end of the 16-week game intervention and after all of the individual teacher interviews, teachers attended a focus group. The purpose of the focus group was to present the preliminary results of interviews, use the results to stimulate discussions, confirm the results with each of the teachers, and indentify missing relevant information. The audio of the focus group was again recorded. The focus group lasted approximately two-and-a-half hours.

Data Analysis

This evaluation program employed a mixed-method approach (Tashakkori & Teddlie, 1998) involving both quantitative and qualitative procedures used concurrently and independently.

Quantitative analysis: Descriptive statistics were calculated for the entire group of student participants and by each of the demographic conditions. A Levene's test was used to test for the assumption of homogeneity of the variance, and the skewness and kurtosis were used to evaluate the normality assumption. Data were entered into repeated measures Analysis of Covariance (ANACOVA). ANACOVA (Type III) was chosen because it allows for the analysis of effects while controlling the relationship of other related measures. Type III Sums-of-Squares was selected because it corresponds to the variation attributable to an effect after correcting for any other effects in the model and is robust to situations with unequal distributions per condition. Because the focus of this evaluation was on the change in criterion measures resulting from the 16-week game intervention while controlling for other relevant variables, three ANACOVA models were examined – one for each criterion measure. The models included the demographic variables: gender (Female, Male), socio-economic status (Normal, Economically Disadvantaged), ethnicity (White, Non-White) while controlling for frequency of game play and frequency of computer use. Thus, the data were entered into 2 Gender x 2 Ethnicity x 2 SES x 2 Criterion Measure (pre-test vs. post-test). Only the two-level interactions with the criterion measures are included within the models. F-statistics, p-values and partial η2s are reported to describe effects. All statistical tests were set at α =.05 level and were analyzed using SPSS v16.

Qualitative analysis: The interview and focus group data were analyzed using a constant comparative qualitative procedure (Glaser, 1965; Glaser, 1967). The constant comparative qualitative procedure was selected because it "is concerned with generating and plausibly suggesting (but not provisionally testing) many categories, properties, and hypotheses about general problems" (Glasser, 1967, p. 104). The constant comparative method involves four stages (Glasser, 1967): 1) comparing incidents applicable to each category, 2) integrating categories and their properties, 3) delimiting the theory, and 4) writing the theory. Each incident in this evaluation was a teacher response to a question, which would be compared to all other responses during each iteration of the data coding process. Members of the evaluation team independently coded each aspect of the teacher interviews, and subsequently, merged their categories and properties together after review by other members of the team. The themes emerging from the categories and properties were then used to generate descriptions of how experienced teachers perceived the use of modern educational games in a K-12 setting.

Results

Quantitative Analysis

Table 2 provides the descriptive statistics for the entire group of participants by demographic conditions, pre-test and post-test measures. There were no severe departures from normality with skewness within the range of +/-1.46 and kurtosis within the range of +/-2.20. No violations were detected for each criterion measure using Levene's test for homogeneity of the variance. As shown in Table 2, there are increases from pre-test to post-test on attitudes towards mathematics, mathematics self-efficacy, and mathematics achievement for the entire group of participants.

Table 2. *Descriptive statistics of criterion measures for each group by pre-test and post-test.*

	Pre-Test			Post-Test		
	Math Attitudes	Math Self-Efficacy	Math Achievement	Math Attitudes	Math Self-Efficacy	Math Achievement
Entire group (*N*=225)	2.92 (0.35)	2.60 (0.38)	11.74 (4.19)	2.96 (0.35)	2.62 (0.34)	12.16 (4.47)
Gender						
Male (*n*=110)	2.88 (0.35)	2.61 (0.42)	11.52 (3.86)	2.94 (0.31)	2.63 (0.36)	11.39 (3.93)
Female (*n*=115)	2.96 (0.34)	2.58 (0.34)	11.95 (4.48)	2.97 (0.37)	2.62 (0.33)	12.89 (4.84)
Socio-economic status						
Disadvantaged (*n*=145)	2.89 (0.35)	2.61 (0.40)	11.34 (4.03)	2.97 (0.33)	2.64 (0.36)	11.59 (3.93)
Normal (*n*=80)	2.97 (0.35)	2.57 (0.34)	12.45 (4.4)	2.94 (0.38)	2.58 (0.32)	13.19 (5.19)
Ethnicity						
White (*n*=117)	2.89 (0.37)	2.60 (0.40)	11.55 (4.33)	3.00 (0.32)	2.63 (0.35)	11.62 (4.43)
Non-White (*n*=108)	2.96 (0.32)	2.60 (0.36)	11.94 (4.04)	2.90 (0.36)	2.62 (0.34)	12.73 (4.47)

Mean (Standard Deviation)

Attitudes towards mathematics: The ANACOVA model for attitudes towards mathematics is shown in Table 3. Student attitudes towards mathematics was found to be statistically significant [$F(1, 219) = 3.86$, $p = .049$, partial η2 = .02], which indicates that overall attitudes towards mathematics significantly and positively changed after the 16-week game intervention from $M = 2.92$ ($SD = 0.35$) to $M = 2.96$ ($SD = 0.35$). However, as illustrated by the partial η 2, only 2% of the variability is explained. Ethnicity had a significant interaction effect at $F(1, 219) = 10.86$, $p < .01$, partial η2 = .05. This finding indicates that although those student participants classified as non-White started with overall higher attitudes towards mathematics (See Table 2), after the16-week intervention, White students had significantly higher changes in their attitudes towards mathematics than their non-White counterparts. Neither students' frequency of computer use, nor frequency of game play significantly interacted with attitudes towards mathematics.

Table 3. *Attitudes towards mathematics repeated measures ANACOVA model.*

Source of Variance	SS	df	MS	F	*p*	partial η2
Attitudes towards math	0.26	1	0.26	3.86	.049	.02
Attitudes towards math x Gender	0.04	1	0.04	0.53	.47	.00
Attitudes towards math x Ethnicity	0.74	1	0.74	10.86	< .01	.05
Attitudes towards math x SES	0.11	1	0.11	1.56	.21	.01
Attitudes towards math x Frequency of Computer Use	0.07	1	0.07	1.00	.32	.00
Attitudes towards math x Frequency of Game Play	0.05	1	0.05	0.67	.41	.00
Error	15.02	219	0.07			

Mathematics self-efficacy: The ANACOVA model for mathematics self-efficacy is shown in Table 4. Mathematics self-efficacy was statistically significant in the model at $F(1, 219) = 6.98$, $p = .01$, partial η2 = .03. This finding suggests that the 16-weeks of game play positively influenced students' confidence in their ability to do mathematics in an academic setting from $M = 2.60$ ($SD = 0.38$) to $M = 2.62$ ($SD =$

0.34). Only 3% of the variability is explained in this change. Unlike the attitudes towards mathematics model, the frequency to which individuals play games in their leisure time significantly interacted with the changes in mathematics self-efficacy from pre-test to post-test at $F(1, 219) = 8.58$, $p < .01$, partial η2 = .04. Thus, the frequency to which students play games in their leisure time moderated the changes in their mathematics self-efficacy.

Table 4. *Mathematics self-efficacy repeated measures ANACOVA model.*

Source of Variance	SS	df	MS	F	*p*	partial η2
Math self-efficacy	0.59	1	0.59	6.98	.01	.03
Math self-efficacy x Gender	0.13	1	0.13	1.48	.23	.01
Math self-efficacy x Ethnicity	0.01	1	0.01	0.06	.81	.00
Math self-efficacy x SES	0.03	1	0.03	0.35	.55	.00
Math self-efficacy x Frequency of Computer Use	0.00	1	0.00	0.03	.87	.00
Math self-efficacy x Frequency of Game Play	0.73	1	0.73	8.58	< .01	.04
Error	18.56	219	0.08			

Mathematics achievement: The ANACOVA model for mathematics achievement is shown in Table 5. Overall mathematics achievement was not statistically significant in the model at $F(1, 219) = 0.08$, $p = .77$, partial η2 = .0, which indicates that although overall mathematics achievement scores increased from pre-test ($M = 11.74$; $SD = 4.19$) to post-test ($M = 12.16$; $SD = 4.47$), the change was insignificant. Another notable result is that none of the individual differences (e.g., gender or SES) significantly interacted with the changes in mathematics achievement.

Table 5. *Mathematics achievement repeated measures ANACOVA model.*

Source of Variance	SS	df	MS	F	*p*	partial η2
Math achievement	0.91	1	0.91	0.08	.77	.00
Math achievement x Gender	22.30	1	22.30	2.03	.16	.01
Math achievement x Ethnicity	11.10	1	11.10	1.01	.32	.00
Math achievement x SES	1.61	1	1.61	0.15	.70	.00
Math achievement x Frequency of Computer Use	2.14	1	2.14	0.19	.66	.00
Math achievement x Frequency of Game Play	0.21	1	0.21	0.02	.89	.00
Error	2406.18	219	10.99			

Student evaluation: The student evaluation survey provided student participants with the opportunity to express their opinions about the DimensionM product. Note one student did not complete the evaluation survey (*n* = 224). The question, responses, and response frequencies for the evaluation survey items are shown in Table 6. As can be gathered, only 8.4% of the student participants indicated that none of the activities in the ST^2L were fun. About 91% of the sample indicated that some or most of the activities in the ST^2L were fun.

Table 6. *Questions, responses and response frequencies to student evaluation survey*.

Question/Response	**Students**	**Percent**
Did you find using DimensionM fun?		
None of the activities were fun (1)	19	8.4
Some of the activities were fun (2)	61	27.1
Most of the activities were fun (3)	144	64.0
How easy or difficult was using DimensionM for you?		
Difficult (1)	17	7.6
Just right (2)	151	67.1
Easy (3)	56	24.9
How well did DimensionM measure your mathematics skills and knowledge?		
did not show my skills and knowledge (1)	26	11.6
allowed me to show some of my skills and knowledge (2)	92	40.9
is a good way to show most of my skills and knowledge (3)	106	47.1
Were any of the activities in DimensionM confusing for you?		
Yes (1)	88	39.1
No (2)	136	60.4

Another important aspect was the level of difficulty that student participants experienced. Only 7.6% of the student participants indicated that using DimensionM was difficult. Approximately 24% indicated that the activities were easy, and more than half of the participants (67.1%) perceived that the activities were just right. Equally important, student participants were also asked to rate how well they thought that DimensionM measured their knowledge and skills. Less than 12% of the student participants indicated the tool was a poor measurement instrument. Approximately 47% of the student participants indicated the tool was a good way for them to demonstrate most of their skills and knowledge.

A final consideration was whether or not any of the students found the activities in DimensionM to be confusing. As can be gleaned, more than 60% of the participants did not find the activities confusing at all. To gain a better perspective of what was confusing; students were provided the opportunity to explain the source of confusion in a free-form response. These results were analyzed and are presented in Table 7. The most frequently cited sources of confusion were related to students not having the ability to respond to math questions and the directions within the game being confusing. Only four students indicated that the whole game was confusing.

Table 7. *Student evaluation of sources of confusion*.

Source of Confusion	**n***	**%**	**Description**
Finding answers	32	48%	Student indicated that they did not understand how to answer math questions.
Directions	14	21%	Student indicated that the game directions were confusing.
Getting started	10	15%	Student indicated that they were confused in the beginning only.
Obstacle course	5	8%	Student indicated that the obstacle course in the multiplayer game was too difficult.
Defending yourself	4	6%	Student indicated it was too difficult to defend their character against attacks.
Whole game	4	6%	Student indicated that everything about the game was confusing.
Motion	3	5%	Student indicated it was difficult to move their character in the 3-D environment.

**Note that the results are based on 66 students providing descriptions.*

Qualitative Analysis

Parental interaction and home game play: A potential barrier to successful integration of games in the classroom can come from the perceptions held by parents or guardians of the students. Nine of the teachers indicated that they had minimal interactions with parents or guardians throughout the program. All parental interactions were focused on student progress, usage of the game at home, and initial concerns and skepticism among parents. Only two teachers indicated that there were some initial concerns from parents about time being taken away from instruction which could impact their child's performance on annual standardized, high-stakes assessments. One teacher explained that he had a few parents tell him that they had seen growth in their children's academic abilities and their love of mathematics. Another teacher also spoke of a parent coming to her to let her know that her child "...absolutely loved the math program" (Teacher, 2009) and this typically quiet child had shown improvement in his social and mathematical skills.

Students were given the opportunity to access the game from their home computers. However, this was not a requirement or expectation of the evaluation program. Although nine of the teachers indicated that students did engage in the game from home, this use was minimal. In most cases, the percentage of students that actually played the game was from 10% to 20% with two teachers stating that there was only about 1% home usage among their students. One of the issues that teachers discussed was that many students were having technical problems installing the game on their computers which could be due to insufficient hardware. According to this teacher, "...the desire was there but the students were unable to make it work" (North Carolina Teacher, 2009). Only one teacher indicated that some parents would not allow their children to play the game at home. During the follow-up meeting, it was expressed by one teacher that the lack of home play could largely be attributed to the fact that a small percentage of their students actually have working computers at home.

Curriculum integration: When asked to rate how difficult it was to integrate the DimensionM product into the math classroom on a scale of one to ten (least difficult to most difficult), all teachers responded with three or less: six of the teachers said that they would rate it at a level of one, one teacher rated it at a level 2.5, and three teachers indicated a level three. These scores suggest that all teachers found the educational games relatively easy to integrate into the regular classroom setting. As shown in Table 8, many strategies were employed to integrate the game into their classrooms and are elaborated on in this section.

***Reward system*:** The game was most frequently used by teachers as a reward system (n = 9). Students could earn *additional* time with the game for showing acceptable behavior or for completing academic tasks (i.e., homework). In fact, one teacher's main source of integration was as a reward system. Students in this class were classified as gifted, and were allowed to play the game only after they finished their work. Another teacher implemented a system where students could earn points for a classroom store to buy things (e.g., pencils). However, this teacher commented that the reward system was not necessary as the students were "completely self-motivated" (Teacher, 2009) to play the game.

On the other hand, it was also used as a consequence for completing work in that one teacher would limit game time if homework was not completed. In this case, students would finish homework during class time and were then allowed to play. The teacher stated that this method had worked and many of the students who, in the past, frequently did not complete their homework started bringing in their homework as they did not want to miss game time.

Concept reinforcement: Eight of the teachers stated that the game was used as a way to reinforce mastery of the subject matter. The game was initially used by one teacher to reinforce basic computational skills which later evolved into a classroom structure where students started making connections between the newly learned concepts to what would happen in the game. He (Teacher, 2009) stated that students "... began to realize what was important in mathematics and why they had to learn it. They saw that if they did not know a particular fact they could not play very well." Another teacher would teach a concept and then use the game as a hands-on activity to reinforce what was previously learned. For example, when he taught a lesson on irrational numbers the students would later go to the game and use their knowledge in a context. Because of this, he began to see that his students were doing better on the quizzes.

Table 8. *Curriculum integration strategies.*

n	Integration Strategy	Strategy Description
9	Reward System	Use game as a reward for good behavior and completing tasks (e.g., homework).
8	Concept Reinforcement	Use of game for mastery of subject matter.
7	Healthy Competition	Encouraging healthy competition to engender motivation (e.g., leadership board).
6	Student Control	Providing students some control over their learning by allowing students to choose new missions, etc.
4	Game Leaders	Using "competent" students (often gamers) as assistants during game play.
3	Differentiated Instruction	Use of the game to tailor to different ability levels of students.
3	Free-time integration	Letting student play (outside of normally scheduled sessions) after completion of class work.
2	Primer	Providing students a brief overview of game mission before engagement.

Healthy competition: Healthy competition was encouraged by seven of the 11 teachers. This competition was seen as a means to engender motivation among the students. The most commonly mentioned classroom component was the use of a “leader board” or a “wall of fame.” Students would compete for the highest scores so that they could see their names listed on the wall or leader board. According to one teacher, students found this very motivating and developed “…a sense of pride and accomplishment to have their names on the leadership board” (Teacher, 2009).

***Student control*:** Six of the teachers described providing students some control over their learning by allowing students to choose their own missions (curriculum is organized by mission in DimensionM). Of these six teachers, two of them used this as the core integration strategy. Rather than taking an approach that only aligned the game play to the curriculum standards, these teachers would allow the students to investigate different missions on their own. With the other teachers, student control appeared to be more of a negotiation between student and teacher. With one teacher allowing students to choose a topic or mission after the day’s lesson was complete and another teacher planning to have students play certain missions some weeks and then on other weeks students were allowed to choose.

***Game leaders*:** With many teachers, the technology and gaming can be a barrier to implementation as they fear that they will be unable to manage the game environment in the classroom since they are not gamers themselves. Four of the teachers combated this issue by having “competent” (i.e. gamers and technology-savvy) students help other students with game and technology issues that they were experiencing. One described these students as “experts” and would rely on them to guide novice students through complex mission scenarios.

Differentiated instruction: Three of the teachers specifically mentioned the integration of the game as a way to differentiate their instruction (Ferdig, 2007) to meet the varying needs of the students in their classrooms. One teacher planned different lessons for students according to their respective academic abilities. She used the instructional modules for her lower performing math students as a way to introduce the math concepts. For her higher performing students, the multi-player games were used for remediation and reinforcement and allowed for a more complex gaming experience. On the other hand, the differentiated instruction used in another classroom was dependent on the particular game being played versus specifically planning out lessons for select groups of students. Students utilized the different components of the game (i.e., instructional modules) as needed within a particular mission.

Free time integration: Outside of the normally scheduled class sessions, three of the teachers described letting students play after completing their class work. One teacher even stated that some students would finish their work in other classes and ask if they could play DimensionM even though they were not in the mathematics classroom. According to these teachers, many of the same students were asking to play so that they could gain a higher position on the leader board.

Primer**:** Prior to having students embark on a particular mission, two of the teachers described providing students with a brief overview of the elements within the mission. One teacher would begin her class sessions with a mini lesson that would include the mathematics and an overview of what to expect within the game. Students were required to take notes during the mini lesson and when they were playing the game. Students would later use these notes in Twitter to blog and reflect on their own work.

Retrospective changes in integration: Teachers offered many insights into what they would do differently if given the opportunity to go back in time and make changes to their integration strategies. The most common response from eight of the teachers was to spend more time using and learning the game on their own. One of the teachers who had not taken the time to actually play the game realized the importance of doing this. She indicated that at one point, towards the end of the intervention, she observed another teacher using the program and realized what her students were missing. By knowing the program better she would have better been able to integrate the game into her classroom. Similarly, six of the teachers would have taken the time to more closely align the product with the state standards. Notably, teachers were provided curriculum maps to the standards at the initial training workshop. However, for many teachers it is more meaningful if they are able to determine this information on their own.

The teachers also discussed changes they would make in terms of different components of the game. Three of the teachers who used the game as a reinforcement strategy said that they would have also liked to use it as a way to introduce different mathematical topics. The instructional module was the most infrequently used component of the game and five of the teachers said that they would have utilized this more often. Three of the teachers stated they would have used the multiplayer component more frequently. One teacher explained that he would have used this more often as the students loved being able to play with and/or against each other. He further stated that the format of the multiplayer game allows the students to have the “power to control what was happening in the game” (Teacher, 2009).

Advice to interested teachers: When asked what advice they would give to other teachers who are considering or planning to integrate modern educational games into the classroom, seven teachers stated that one must take the time to play and become familiar with the game. One teacher wished that he would have looked through everything first and thinks that it is important to understand the program to properly plan for each class session because what works for one class may not work for another. Similarly, another teacher also agreed that one needs to take the time to play because "If you don't play it, you do not know what you are experiencing" (Teacher, 2009). While playing the game is important, four teachers agreed that taking time to align the game with the curriculum is also a necessity when integrating.

According to two of the teachers, flexibility is important when implementing similar types of games in the classroom. One teacher talked about the importance of not only being flexible but willing to negotiate the teacher control of the classroom. When students are playing the game you do not have control over the problems they are doing or their abilities to play the game. He explains that the environment will be chaotic during the first couple of weeks while the students are trying to understand the dynamics of the game. During that time he said his role was to answer questions all the time. Later he said the room environment completely changed as it was generally silent especially during single player play. However, the multiplayer game was the complete opposite. The students during multiplayer sessions were excited and often speaking loud which can appear to be completely chaotic. He feels that many teachers will have problems dealing with that kind of environment initially. Along with this flexibility, four of the teachers expressed the importance of allowing students to facilitate or take the lead. One teacher indicated that the teachers do not really need to know everything in terms of the game as the students can help with this, but the teachers do need to have the knowledge of the mathematics that is included within the game.

A variety of suggestions were offered regarding the different components of the game. Two teachers felt that the multiplayer portion of the game should be introduced last. Another teacher said the instructional modules should be taught first, then single player, and then multiplayer. She stated that once the multiplayer modules were introduced, the students do not want to do anything else. Two of the teachers felt that implementing the instructional module first was important while three of the teachers indicated that pre-teaching the math that was needed for the missions was also important.

Implementing new materials into the classroom is often a source of fear for many teachers. Three of the teachers expressed that individuals should not be nervous about integrating similar types of games into the classroom. These same three teachers talked about their fears prior to the program being implemented, and many of these fears revolved around the technological aspect of the game. One teacher even felt that he would not be able to successfully integrate the game but found it relatively easy once he started. One of the teacher's fears subsided with the support of her colleagues. Two other teachers also express that having this support is important for successful integration.

Student-to-student interactions: The game appears to have influenced the student-to-student interactions in a variety of ways. These student-to-student interactions are summarized in Table 9. All of the teachers (100%) mentioned that they observed peer-mentoring and tutoring with a willingness to help each other while playing the games. Within these interactions, three teachers mentioned that students were simultaneously competing and working together. One found that students were assisting each other with content and strategies during both the single and multi-player missions. However, when the multiplayer missions were played this assistance would turn into simultaneously competing with each other and communicating by “screaming across the room” (Teacher, 2009). One teacher describes a particular scenario that was observed during a single player game.

> “This past Friday, these three girls are sitting next to each other. They are never in the same class but we had something special going on so all three of them are sitting beside each other. They were doing the same missions; they were all basically going at the same pace. And in the first mission they were all helping each other but by the second mission not everyone got the same score, someone got the bronze, and it changed. I’m not going to help you now. You got higher than me so now I’m not going to help you. So then it was a little bit different. They were a little bit more quiet and they were then doing their own thing. It was interesting to see but they were totally on-task and they are three girls that are normally off-task and, you know, kind of day dreaming or talking to each other. They were just perfect. It was just perfect. If I could have taken a picture of it, it would have been amazing. Just that they were so competitive and also very helpful to each other. I can’t get through there, will you just please help? Oh… all right…I’ll help you (sigh). But I’m not going to do it again” (Teacher, 2009).

Table 9. *Student-to-student interactions observed.*

n	**Student Interaction**	**Interaction Description**
11	Mentorship	Peer mentoring and tutoring and a willingness to help each other during game play.
5	Emerging Leaders	The quiet kids (or others) were assuming leadership roles during game play.
4	Concurrency	Simultaneous competing and cooperation during game play.
3	Socialization	Socializing across social groups during game play.
3	Willingness to Seek Help	Students were willing to ask for help during game play.
3	Heterogeneous	Students grouping themselves into heterogeneous grouping on their own during game play.
2	Boastful	Students were being boastful during game play.

Within these student-to-student interactions, three of the teachers observed students socializing across normal social groups. One observed many of her students that would not normally hang out or interact with each other talking more as they now had the game in common. Students would find that a member from the “other” group would often know more about the game which gave them an opportunity to talk and learn from each other. This created more synergy across diverse students.

Three of the teachers mentioned that students were more willing to ask for help. One teacher discovered that many of her “at-risk” students were more apt to seek out help from their peers because all of the students felt like they were equal, and if they made a mistake, it was “okay”. Another teacher found that her students were more willing to ask for help because they wanted to know the math. These students were neither ashamed nor afraid and did not care that they did not understand the concept at first. They wanted to know the math to play the game.

As some students were becoming more open to asking and receiving help, others were beginning to show their leadership skills. Five of the teachers mentioned that some of their quiet students were rising up and taking a leadership role. Two teachers noted they were surprised by the leaders that emerged in their classroom. One further explained that the leader was not the type of child that she would normally expect to take a leadership role, and it was nice to see him find somewhere to shine and build self-esteem.

Classroom behavior and student-to-teacher relationships: Five teachers indicated that the integration of DimensionM into the regular classroom setting resulted in students being more motivated to play the game and even come to class. These teachers found students being more attentive, more alert, and asking more questions so that they could play the games more efficiently. During the focus group, teachers were asked if they thought the relationship had changed between them and their students as a result of integrating the educational game. All teachers (100%) answered that the relationship had changed indicating that many felt that the students now saw them in a different way. The teachers described a closer, more personal connection to their students. One teacher stated that, "students find gaming exciting and the mere fact that I was offering it in my classroom made a connection. Made me – 'more cool' to them" (Teacher, 2009).

Twenty-first century skills: One of the many goals in education is to prepare students so that they are marketable, employable, and ready for citizenship. To do this, students need to not only have the content knowledge but also possess the 21st century skills (Johnston & Packer, 1987). When asked if teachers observed any of these skills during this 16-week intervention, all teachers (100%) mentioned the students were collaborating and cooperating with each other while engaged in the game. It was also pointed out that this collaboration was self-initiated versus teacher imposed and done in a positive way. Problem-solving was mentioned by ten of the teachers as students were motivated to solve the problems in order to progress through the game. Leadership was mentioned by eight of the teachers. Students who were better at mathematics and/or had greater technological skills helped and directed others.

Technical and curriculum challenges: With the adoption of any instructional product, there is bound to be some curriculum challenges along the way. Four teachers reported that the most consistent challenge was not knowing enough about the game. These teachers felt that if they could have taken more time to explore the different missions they would have been better able to implement the program in the classroom. Time itself was also a challenge for four of the teachers. Teachers mentioned that they wanted to have more time implementing the product beyond the 16-week intervention and would have liked to have been able to offer more classroom sessions but having access to the computers became an issue.

New technology is a fear for many teachers and often a deciding factor for whether or not a particular computer program is adopted into a classroom. The most consistent challenge that teachers faced with respect to technology was the freezing of the game screen which would require the student to exit the game and reboot the computer. This was experienced by 10 of the teachers. However, teachers did say that this happened only occasionally. Thirty-six percent of the teachers indicated some issues with logging onto the online modules.

Overall teacher evaluation: When teachers were asked if they would continue using DimensionM in their classrooms, all (100%) indicated that they would if it was available. Teachers also commented on the impact of the product on students' mathematics achievement and motivation. One hundred percent of the teachers believed that the product had an impact on student motivation. While only eight of the teachers were willing to state conclusively that the product directly impacted mathematics achievement, the remaining teachers hoped that it (DimensionM) did because they wanted to continue using the product.

Discussion of Evaluation

This evaluation has resulted in several key findings. We summarize these findings by both the quantitative and qualitative aspects of the evaluation. Interpretation of the results, however, must be viewed within the limitations of this evaluation program. The design was quasi-experimental in that it did not involve a comparable control group receiving an alternative treatment and random assignment of student participants. Rather, the evaluation examined relationships among several related criteria while controlling for prior knowledge, attitudes, and self-efficacy. The validity and the reliability of the evaluation are limited by the honesty of the student participants' responses to the instruments used. Also, some of the measures employed in this evaluation lacked strong internal consistency reliability (< .7) and the only form of control for a test effect was the scrambling of items and distracters from pre-test to post-test. Finally, using the status of whether a student is on free or reduced lunch as the only proxy for SES may not accurately represent this population. The evaluation should be perceived as exploratory and illustrative of initial findings rather than conclusive evidence.

Quantitative Findings

Similar to earlier research (Ke, 2008; Ke & Grabowski, 2007; Lopez-Morteo & López, 2007; Rosas et. al., 2003), the results support the claim that educational game play positively and significantly influences students' overall attitudes towards the discipline of mathematics. This finding appears to be a reproducible and generalizable finding across different educational game integration contexts. What is unique about this evaluation's contribution is that even after statistically controlling for several other relevant measures (e.g., frequency of game play), the robust effect still manifested itself. The results are especially important as attitudes towards mathematics play a central role in the learning of mathematics as they are frequently used as reliable predictors of long-term achievement in mathematics (Aiken, 1970).

The second noteworthy finding from this evaluation is the significant and positive change detected in students' self-efficacy in mathematics. The construct of self-efficacy is distinctly different than one's attitudes towards mathematics in that it signifies an individual's beliefs concerning his or her ability to perform mathematical tasks (McLeod, 1992). A student may have positive attitudes towards the field of mathematics, but low confidence in their ability to do mathematics which can negatively impact his or her mathematical performance. Schunk (1984) notes that self-efficacy is related to decisions about which activities an individual will choose to participate in, how much effort they will expend on these activities, and how long they will persist on these activities. The fact that students' self-efficacy in mathematics positively changed after the 16-week intervention provides further evidence that educational gaming environments may positively influence the construct (Lu, Lee, & Lien, 2008; Thomas, Cahill, & Santilli, 1997), and suggests that future research of educational game play in mathematics should include this relevant measure.

The third finding from this evaluation was that after the game intervention a significant change in the mathematics achievement scores from pre-test to post-test was not detected. This finding is consistent with some of the previous research (Ke, 2008), but conflicting to others (Ke & Grabowski, 2007; Kebritchi, 2008; Laffery et. al., 2003; Rosas et. al., 2003). What's more, this finding seems to contradict the previous two findings of this study in that both attitudes towards mathematics and self-efficacy in mathematics have been shown to positively correlate to mathematics achievement (Aiken, 1970; Betz & Hackett, 1989). We believe the explanation for this inconsistency may be attributable to the duration of the intervention (16-weeks), the frequency of game play sessions (one time per week), the way in which the game intervention was woven into instruction, the low-stakes nature of the assessment, and the experience levels of the teachers integrating the game. Though longer than some studies, it may be that the 16-week duration was not long enough and the students played the game too infrequently for the intervention to have a meaningful effect.

Further, as noted, the majority of the teachers reported using the game as a reward system and for concept reinforcement. However, games are capable of supporting several different instructional methods, including cooperative learning (Ke & Grabowski, 2007), problem-based learning (Squire, 2003), experiential learning (Kiili, 2005), differentiated instruction (Ferdig, 2007), and others. It is more than conceivable that the instructional method used with the medium is what positively influences mathematics achievement, or more specifically, the way the game is designed and used in a classroom setting. Teachers were responsible for choosing how the games was integrated into the classroom, so it is also possible that teachers required more time and experience (as noted in qualitative results) to effectively integrate the game in their classrooms. It is also possible that students did not take the assessment as seriously as intended since it did not count towards their grades. Of course, another alternative is that the educational game play does not meaningfully impact mathematics achievement. Regardless, more research is necessary to make conclusive remarks about the fidelity of educational game play influencing mathematics achievement.

Another key finding is the statistical insignificance of the many ancillary variables (gender, ethnicity, SES, frequency of computer use, and frequency of game play) included in the models for statistical control. Across the three models, only two of the variables significantly interacted with the criterion measures: ethnicity significantly interacted with attitudes towards mathematics, and frequency of game play significantly interacted with self-efficacy in mathematics. This finding is contrary to intuition and the recommendations of several researchers. For example, De Jean, Upitis, Koch, and Young (1999) suggest that gender plays a key role in learning effectiveness of the games. However, gender did not interact with any of the criterion measures, analogous to previous research (Ke & Grabowski, 2007). Further, the SES of the students, which has been frequently connected to technology access and use in the literature (Hohlfeld, Ritzhaupt, Barron, & Kemker, 2008), did not significantly interact with the criterion measures. These results call into question which variables truly moderate the influence of educational game play on affective and performance measures in mathematics.

Finally, students' evaluation of DimensionM product was positive. More than 90% of the student participants indicated that some or most of the activities were fun, and approximately 67% felt the activities were just right in their level of complexity. Further, about 89% believed DimensionM allowed them to demonstrate some or most of their mathematics skills and knowledge.

Qualitative Findings

What can be concluded from the analysis of teachers who have integrated a modern educational game into a formal K-12 setting? We believe these results provide compelling evidence that the use modern of educational games in a formal K-12 setting serves as an agent for change in instructional practice, student-to-student and teacher-to-student relationships, the skills and dispositions of students. We preface these changes, however, with two antecedents: professional development and support for teachers. Professional development is a widely recognized antecedent to successful technology integration in education (Boardman & Woodruff, 2004; King, 2002; Schrum, Burbank, Engle, Chambers & Glassett, 2005). Here, teachers were provided access to two workshops tailored specifically for integrating the DimensionM game into their classrooms. Teachers need access to programming that will prepare them for the many complexities in a gaming classroom.

Further, in a gaming classroom, the necessity for quality technical support is attenuated. Rapid responses to teacher and student technical problems on the part of technology support specialists or coordinators are instrumental for a successful technology-supported instructional experience (Cuban, Kirkpatrick & Peck, 2001). If unsolvable technical glitches occur frequently, then teacher confidence in the technology diminishes (Cuban, Kirkpatrick & Peck, 2001). Teachers in this program were provided support not only from their computer-resource teachers, but also from district, company and evaluation team personnel. We believe that without these two key ingredients, the integration of modern educational games will be unsuccessful.

With this in mind, we note several curriculum integration strategies amongst participating teachers, including the use of a modern educational game as a reward system, for concept reinforcement, for differentiated instruction, and more. Teachers also tried different things that they previously had not done, such as encouraging healthy competition, affording students control over their learning experience, and using the expertise of their students to “lead” other students in their learning experiences. Some teachers also noted permitting “shouting” across the room during game play. In many ways, these changes are indicative of a shift from a teacher-centered (aka Sage on Stage) environment in which the teacher dictates the learning experience to a student-centered (aka Guide on the Side) environment in which students have more control over how and what they learn (King, 1993).

In terms of student behaviors observed by teachers, the results are most intriguing. Teachers observed students change their interactions in that 100% observed students mentoring and tutoring each other. Further, teachers noted a willingness of students to seek help when needed, socialization across social "groups", and simultaneous competing and cooperation during game play. Teachers also noted several 21st century skills, including problem-solving, collaborating and cooperating, leadership, and technological skills. Several teachers also reported improved relationships with their students as a result of integrating the game into their classroom.

These findings are positive in that teachers are trying many interventions to lead to these types of changes (e.g., cooperative learning programs). The fact that modern educational games appear to be a natural catalyst for these changes, makes them a desirable asset to any educational enterprise. Given the limited number of curricular and technical challenges coupled with the relative ease of integration, these results support school districts providing teachers with professional development, technical support, and modern educational games, like DimensionM, on a larger scale. However, this level of adoption should be contingent upon continued research.

Recommendations

As the results of this evaluation have implications to several stakeholders, it is important to provide recommendations based on the results to other educators, educational researches, and game designers to inform future endeavors.

***Educational game designers*:** Many problems mentioned by the teachers were issues with technology within the school networks and not issues from the game itself. We recommend, however, that companies that design these games continue to offer some type of help line for the teachers and instructional staff to call when problems do arise. The main complaint from all of the teachers was that the games would intermittently freeze requiring the students to exit the game and reboot the computer. We recommend that prior to integration (and sale of the product); the games be tested on machines that are located in schools because many school configurations are sub-standard to industry.

Providing teachers with a clearly written set of game instructions is imperative in that teachers may not know how to play the game and can only support the subject matter content. Similarly, tutorials or handouts for how to play the game, suggestions on ways to integrate the game into the classroom, and caveats on integration may be effective materials that come with the educational programs.

Reporting mechanisms for educational games should be detailed, current, and flexible. That is, the data should update on a regular basis and should provide the teacher many different ways of viewing the information (e.g., graphs, detail and summary reports). Providing teachers with training on how to access and interpret scores earned by individual students would help to document progress which may be used for classroom grading or participation purposes. For students, the scores earned in the games are part of the motivation for continued usage. Information regarding how points and designations (e.g., medals in DimensionM) are earned needs to be clearly articulated to the students and teachers which could be found on an informational page within the product website. Students want to know how scores are computed and what is considered an acceptable score to earn a designation.

We would also suggest that the single player games be structured so that they can be saved mid-mission or have different points along the way where the mission can be stopped and returned to at a later date. Schools function on a structured schedule which often means that games cannot be completed in the allotted time. If students could restart their missions at a specified point, it would allow them the opportunity to continue without having to start from the beginning which many students find frustrating. We also recommend designing the game in such a manner that guess and check methods for solving problems would result in lower scores. Teachers did report some students were simply “mashing buttons” to earn points. This could possibly force students to emphasize the learning of mathematics versus just playing the game.

Parents are an important part of gaming in the academic setting. We suggest providing materials for the parents that would highlight ways that they can interact with their child while using the game and highlight the effects of the game on student learning. A possible suggestion is to provide parents access to the game as part of the licensing with schools. Another possible consideration would be to designate rooms where parents can play the game with their child or even a multiplayer game where they can compete against other families.

Educators**:** One of our main recommendations for teachers who are planning to integrate the game into the classroom setting is to take the time to learn about the game they have chosen. For many teachers, this would include actually playing the different missions and navigating through the different sites. We do realize that for many teachers, actual playing of the game is a barrier to implementation. Although we do feel that teachers need to know the general information about the game, the students can be great teachers when it comes to learning how to operate and maneuver within the game. Teachers need to also have a clear implementation plan or strategy prior to introducing the game into the classroom. In order for students to benefit from the gaming experience, they need to be allowed to play the game on a regular basis and not just when they are being rewarded for turning in work or behaving appropriately. It is also imperative that this strategy or plan include how the game will align with the curriculum standards and instruction.

We also recommend that teachers should shift to a student-centered environment and allow student leaders to emerge. These leaders will often help with the organization of the multiplayer games and can be great guides when it comes to students learning how to actually play the game. The environment that is created while playing the game is different than the typical classroom. Teachers should be comfortable and have a plan for dealing with "good noise". Students get excited and competitive during the multiplayer games which is most often healthy competition and generates more noise in the classroom that traditional instruction. Equally important, administrators should be supportive of teachers that are willing to try modern educational games in their classrooms. Because we are now living in an environment that is filled with technological advances, students should be provided with the tools that they see and use on a regular basis.

Two of our most important recommendations to teachers are 1) do not be threatened or scared by modern educational games and 2) implement in groups. While many teachers will likely not be gamers, this should not prohibit their use in the classroom. Only three of the teachers in this program played games and several had initial concerns about the integration. Though the integration of a modern educational game is going to inevitably result in changes, we believe that teachers should welcome these changes in their classroom. Teachers also suggested that having access to colleagues that were using the same product and experiencing similar challenges made it much easier to manage. Thus, implementing in groups within schools will promote a community of practice to share ideas and assist in implementations.

Educational researchers: We believe that much of the empirical work on the influence of educational game play on mathematics is confounded by several factors. Across the studies reviewed in this white paper alone, we identified differences in the type of games used, the duration and frequency of the interventions, the dependent and independent measures examined, the methodologies employed, the age of the participants, and the educational setting. Put simply, we have very little generalizable knowledge on this topic. We need more researchers to spearhead this complicated domain in contexts that can be replicated by others.

An important characteristic of modern educational games in comparison to other traditional methods of instruction is that instruction and assessment can be seamlessly integrated into the same environment. Specifically, all of the user interactions (e.g., key strokes) within the games can be recorded in server logs that can serve a multitude of purposes (Feldon & Kafai, 2008). These user interactions represent many different types of measurements ranging from achievement data (e.g., accuracy) to timing data (e.g., speed) to behavioral data (e.g., on-task). While some research has already started to use these data to document effects on student learning (Feldon & Kafai, 2008), we have really only scratched the surface in this regard. Future research should consider using these data to further explain effects.

Further, we believe two things must be taken into consideration in future research endeavors. First, all of the research reviewed here only includes participants in a single research setting. That is, none of the studies published to date have examined the influence of educational game play on mathematics achievement longitudinally, taking several measurements at different points in a students' development. This initiative will have to be addressed in the near future for our work to make consequential impact on educational practice and reform. Second, we believe that future research will also need to focus more heavily on the design of games and how they are integrated into the classroom. As noted by Clark (1983), it is not the medium but rather the method that influences learning. So, future research should specifically address different genres of games and their use with different instructional methods.

We believe that the qualitative findings, at minimum, beckon further research to confirm the observations of teachers. For example, these results suggest that integrating modern educational games serves as a catalyst to change instructional practices from a teacher-centered to more of a student-centered learning environment. By using standardized observational instruments, like the Classroom Observation Measure (COM), empirical research could be conducted to observe the instructional practices of gaming classrooms. Research in the realm of educational gaming is open-ended with many opportunities for improvement and innovation, especially in mathematics education.

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Appendices

Appendix A. Teacher Interview Questions.

1. How many years have you been teaching in the K-12 classroom or setting?
2. Are you a gamer?
3. How many years have you been teaching with computers?
4. Is this a Title I school?
5. Have you ever used a game like DimensionM in your classroom?
6. How frequently do you meet with your classes each week?
7. How long are your class sessions?
8. On average, how often do your students play DimensionM on a weekly basis?
9. Which aspects of the DimensionM product did you use?
    a. Instructional modules
    b. Single player games
    c. Multiplayer games
10. Did any of your students use DimensionM at their homes? If so, how many do you estimate?
11. Did the parents of your students provide you any feedback about the students playing DimensionM? If so, what did they say?
12. What was the classroom configuration in terms of computer access (1:1, pairs, groups, etc)?
13. Please describe your strategy for integrating the DimensionM product into your curriculum.
14. If you could go back in time, would you do anything differently in terms of your integration strategy? Please describe.
15. On a scale of 1 – 10 (1-least, 10-most), how difficult was it to integrate DimensionM into your curriculum? Please elaborate as to what was or was not difficult in terms of integration.
16. If you could provide tips, techniques, and caveats to other teachers interested in using DimensionM, what would they be?
17. How did integrating DimensionM influence your regular classroom sessions? Please describe.
18. Please describe the technical challenges you encountered integrating DimensionM into your classroom.
19. Please describe the curriculum integration challenges you encountered integrating DimensionM into your classroom.
20. What types of behaviors did you observe as your students played DimensionM? Please describe in terms of:
    a. Appropriate behaviors
    b. Inappropriate behaviors
21. How did you address the inappropriate types of behaviors during class sessions?
22. What types of student-to-student interactions did you observe while students were playing the game as compared to their regular classroom interactions?
23. Did you observe any 21st century skills as your students played DimensionM? Please describe.
24. What is your overall evaluation of the DimensionM product?
25. If you had the opportunity to continue using DimensionM, would you?

26. Did any of your classes stand out from the rest? For example, were certain classes more engaged than others? If so, can you think of something that influenced this?
27. What was your students overall reaction to DimensionM?
28. Do you believe that DimensionM had a direct impact of mathematics achievement? Please describe.
29. Do you believe that DimensionM had a direct impact on student motivation? Please describe.
30. Is there anything else that we did not talk about that you would like to say?

Appendix B. Background survey information.

1. Gender:

Male
Female

2. Age:

______

3. Race:

White
Black
Hispanic
Asian
Other

4. Are you on a free or reduced lunch program?

Yes
No

5. Do you usually speak English with your family at home?

Yes
No

6. How long have you been using computers?

Less than one year
One to three years
Three to five years
More than five years

Appendix C. Frequency of Computer Use.

How often do you use a computer at these locations?

Scale:
5: Almost every day
4: A few times each week
3: Between once a week and once a month
2: Less than once a month
1: Never

At home
At school
At other places

How often do you use:

Scale:
5: Almost every day
4: A few times each week
3: Between once a week and once a month
2: Less than once a month
1: Never

The Internet to look up information about people, things, or ideas?
Games on a computer?
Word processing (e.g., Microsoft Word, Works)?
Drawing, painting or graphics programs on a computer?
Presentation software (e.g., Microsoft PowerPoint, Apple Keynote)?
Spreadsheets (e.g., Microsoft Excel, Works)?
Video Editing (e.g., Moviemaker, iMovie)?
A computer for electronic communication (e.g., e-mail, instant messaging)?
The Internet to download software, music, or files?
The computer to help you learn school material?

Appendix D. Frequency of Gameplay.

How often do you play the following types of games?

Scale:
5: Almost every day
4: A few times each week
3: Between once a week and once a month
2: Less than once a month
1: Never

Skill-and-action games
Adventure games
Role Playing games
Strategy/simulation games
Racing games
Fighting games
Puzzle games
Sports games
Other (e.g., Educational)

Appendix E. Attitudes towards Mathematics and Mathematics Self-Efficacy.

To what extent do you agree with the following statements?

Scale:
4: Strongly agree
3: Agree
2: Disagree
1: Strongly disagree

Attitudes towards Mathematics
Mathematics is an important field of study.
I enjoy studying mathematics.
A calculator is necessary when doing mathematics.
Many mathematical concepts are too difficult to understand.
Mathematics is not very useful in the real world.
I often do not care whether I get math problems correct or incorrect.
Mathematics is more something I have to do than something I choose to do.
Mathematics is best left to mathematicians.
I often think of other things while attempting to solve math problems.
Knowing why mathematics works is as important as knowing how it works.
Mathematics is a powerful tool.

To what extent do you agree with the following statements?

Scale:
4: Strongly agree
3: Agree
2: Disagree
1: Strongly disagree

Self-Efficacy in Mathematics
Performing mathematical computations makes me anxious.
I experience great difficulty in learning mathematics.
Solving math problems is easy for me.
I believe I will never be good at doing mathematics.

Appendix F. Student evaluation survey.

Did you find using DimensionM fun?

Most of the activities were fun
Some of the activities were fun
None of the activities were fun

How easy or difficult was using DimensionM for you?

Easy
Just right
Difficult

How well did DimensionM measure your mathematics skills and knowledge?

DimensionM was a good way to show most of my skills and knowledge
DimensionM allowed me to show some of my skills and knowledge
DimensionM did not show my skills and knowledge

Were any of the activities in DimensionM confusing for you?

Yes
No

If yes, please describe what was confusing to you.

Appendix G. Mathematics achievement (Pre-test).

1. Which of the following is the ***best*** estimate of the following product? 13.9624 x 0.501
   a. 0
   b. 7
   c. 13
   d. 14
2. The Thomas family went for a Sunday drive. Before they left Mr. Thomas noticed the gas tank was ¾ full. When they returned home the gas tank $\frac{1}{3}$ full. If the gas tank holds 18 gallons, how many gallons of gas did the car use on the drive?
   a. $6\frac{1}{4}$
   b. $7\frac{1}{2}$
   c. $8\frac{1}{2}$
   d. $9\frac{1}{2}$
3. Students in four classrooms were asked if they planned to participate in a school sport for the coming year. Which group had the ***highest*** percent reply yes?
   a. Classroom A – 15 yes out of 24
   b. Classroom B –30 yes out of 42
   c. Classroom C – 12 yes out of 17
   d. Classroom D – 18 yes out of 26
4. Which of the following is closest to 1?
   a. $\frac{7}{112}$
   b. $\frac{56}{76}$
   c. $1\frac{8}{10}$
   d. $1\frac{4}{9}$
5. Over the past 8 years the property tax value of Jake's house increased from $85,000 to $93,000. By about what percent did the property tax value increase?
   a. 8%
   b. 9%
   c. 11%
   d. 13%

6. Mr. Jones purchased a new compact disc (CD) player for $97.19 including tax. The CD player had a sticker price of $89.99. To the nearest whole number, what percent sales tax did he pay?
    a. 6%
    b. 7%
    c. 8%
    d. 9%
7. Mr. Jones purchased a new compact disc (CD) player for $97.19 including tax. The CD player had a sticker price of $89.99. To the nearest whole number, what percent sales tax did he pay?
    a. 6%
    b. 7%
    c. 8%
    d. 9%
8. There were approximately 113,800,000 people living in Nigeria in 1999. How is this number written in scientific notation?
    a. 113.8×10^6
    b. 11.3×10^7
    c. 1138.0×10^5
    d. 1.138×10^8
9. Write the following in scientific notation: 0.000006
    a. 6.0×10^{-6}
    b. 0.6×10^{-6}
    c. 6.0×10^{-6}
    d. 6.0×10^{12}

10. The radius of an atom is one nanometer which is approximately 3.937×10^{-8} of an inch. What is this length expressed in standard notation?

    a. 0.000000003937 in.
    b. 0.00000003937 in.
    c. 0.0000003937 in.
    d. 0.000003937 in.
11. Which expression is equivalent to $3^3 \cdot 36 \cdot 2^4$?
    a. $2^6 \cdot 3^5$
    b. $2^8 \cdot 3^6$
    c. $2^6 \cdot 3^6$
    d. $2^8 \cdot 3^5$

12. The area of a square is 800 square meters. The length of its sides is between which two numbers?

    a. 27 and 28

    b. 28 and 29

    c. 200 and 201

    d. 400 and 401

13. One astronomical unit (AU) is the average distance from Earth to the sun. This distance is about 1.5×10^8 kilometers. What is the equivalent distance in kilometers for 3 astronomical units?

    a. 4.5×10^{22}

    b. 1.5×10^{22}

    c. 4.5×10^8

    d. 4.5×10^4

14. The mass of an electron is 9×10^{-28} grams. A proton weighs 1,836 times as much as an electron. Which of the following represents the weight, in grams, of a proton written in scientific notation?

    a. 1.0836×10^{-24}

    b. 1.0836×10^{-28}

    c. 1.6524×10^{-24}

    d. 1.6524×10^{-28}

15. What number is 5 less than four times the absolute value of -7?

    a. -33

    b. -23

    c. 23

    d. 33

16. Which of the following is a true statement?

a. $|{}^{-}3| = {}^{-}2 + |{}^{-}1|$

b. $|{}^{-}3| = |{}^{-}2 + 1|$

c. $|{}^{-}3| = |{}^{-}2| + {}^{-}1$

d. $|{}^{-}3| = |{}^{-}2 + {}^{-}1|$

17. The expression $4(5 - 3y) + 3(y+2)$ is simplified in the following steps.

Step 1	$4(5 - 3y) + 3(y+2)$	$= 20 - 12y + 3y + 6$
Step 2		$= 20 - 9y + 6$
Step 3		$= 20 + 6 - 9y$
Step 4		$= 26 - 9y$

Which property was used to go from Step 2 to Step 3?

a. Commutative property

b. Additive identity

c. Associate property

d. Distributive property

18. Simplify: ${}^{-}10 + 2(4 + w)$

a. ${}^{-}32 - 8w$

b. ${}^{-}18 - 2w$

c. ${}^{-}2 + w$

d. ${}^{-}2 + 2w$

19. Simplify: $8y^2 - 3y - 5y + 2y^2$

a. $8y^2 + 8y$

b. $8y^2 + 8y$

c. $10y^2 - 8y$

d. $10y^2 - 10y$

20. Which of the following is the perimeter of a square whose side measures 2a + 3?

    a. 11a

    b. 8a + 7

    c. 8a + 3

    d. 8a + 12

21. What additional information is needed to solve this problem?

Mary paid $2.20 for a sandwich, a cup of fruit, and a pint of milk. If the sandwich costs $0.95, what was the cost of the fruit?

    a. The cost of a pint of milk

    b. The total cost of the lunch

    c. The size of the cup of fruit

    d. No additional information is needed.

22. Sam has a total of 15 cows and horses. He feeds each animal 2.3 pounds of grain each day. Each day he also puts out 10 extra pounds of grain for the animals. How much grain does Sam use each week?

    a. 44.5 pounds

    b. 104.5 pounds

    c. 251.5 pounds

    d. 311.5 pounds

23. Jackie can mow the lawn at his house in 45 minutes. Chris can mow the same lawn in 50 minutes. Which question would require additional information to find the solution?

    a. How much more than Chris did Jackie charge to mow the lawn?
    b. Who mows the lawn faster?
    c. If Jackie works alone, how much of the lawn will be mowed in 30 minutes?

24. Garrett made a toy box for his younger sister. The inside of the entire toy box, including the lid, is 15 in. wide, 30 in. long and 12 in. tall. Garrett wants to line the inside, including the lid, with purple cloth. How many square feet of cloth should he buy?
    a. 3.125 ft2
    b. 8.125 ft2
    c. 13.75 ft2
    d. 28.5 ft2

25. What is the ***approximate*** volume of a cone with a radius of 6 inches and a height of 9 inches?
    a. 113.04 in.3
    b. 339.29 in.3
    c. 1017.88 in.3
    d. 1356.48 in.3

26. Juan built a squre pyramid in the sand. He built a second pyramid with the same size base that was one third as tall as the first one. What would be the volume of the second pyramid?
    a. The volume would be 1/9 as much as the first pyramid.
    b. The volume would be 1/3 as much as the first pyramid.
    c. The volume would be 3 times as much as the first pyramid.
    d. The volume would be 9 times as much as the first pyramid.

27. For a classroom assignment, Ashley needs to estimate the mass of her cheese sandwich. Which would be the ***most reasonable*** estimate?
    a. 200 grams
    b. 3 kilograms
    c. 27 centigrams
    d. 300 milligrams

28. Some business people took a flight from Greenville to Hickory, a distance of approximately 300 miles. The plane's rate of speed was 225 mph. How long did the flight take?
    a. 45 min
    b. 1 hr
    c. 1 hr 20 min
    d. 1 hr 30 min

29. Trent is using the linear equation $x + y = 2$ to plot a line on graph paper. If $(x, -4)$ are the coordinates of a point on the line, what is the value of x?
    a. -4
    b. -3
    c. 5
    d. 6

30. Solve: $x/3 + 5 = 2$
    a. $x = -9$
    b. $x = -1$
    c. $x = 1$
    d. $x = 9$

31. The x-intercept of a line is the point on the graph where $y = 0$. What is the x-intercept for the graph of

    $4x + 3y = 12$?
    a. (4, 0)
    b. (3, 0)
    c. (—3, 0)
    d. (—4, 0)

32. Patrice and Tom needed to report the results of a survey regarding the favorite snack food of the students at Milton Middle School. How could the experiment be done to produce a random sampling of 100 students?
    a. Ask the students as they get off the school buses.
    b. Ask the opinion of all the teachers at the school.
    c. Ask all the students who are in the school cafeteria during one day.
    d. Ask every 20th student randomly until 100 students have been asked.

33. A bag is filled with spools of thread. Five are red, 6 are yellow, and 4 are white. After a spool is picked from the bag, it is not replaced. On the first and second tries, no white thread is picked. What is the probability of picking white thread on the third try?
    a. $\frac{4}{13}$
    b. $\frac{4}{15}$
    c. $\frac{1}{13}$
    d. $\frac{1}{15}$
34. Matt has a bag containing 12 one-dollar bills and 8 five-dollar bills. Without looking, he pulls out one bill and places it on the table. He then picks a second bill from the bag. What is the probability he will have 2 five-dollar bills?
    a. 8/20 · 7/19
    b. 8/20 · 7/20
    c. 1/8 · 1/7
    d. 1/8 · 1/8
35. Juan rolled a pair of fair number cubes labeled 1 to 6. If he rolled the pair 210 times, for ***about*** how many of the rolls should he expect the sum to be a seven?
    a. 21
    b. 35
    c. 45
    d. 70