BrainQuake Game-Based Learning and Assessment Applications with Direct Representation of Mathematics:

A Feasibility Study

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Overview of Study

As part of the Phase II Small Business and Innovation Research grant (awarded by the U.S. Institute of Education Sciences) BrainQuake developed two puzzle suites: 1) the Tiles puzzle, which was developed to support algebraic reasoning, and 2) the Tanks puzzle – which was developed to support proportional reasoning. WestEd was contracted by BrainQuake to conduct an independent evaluation of the new puzzles' impact on student outcomes. Because the flagship puzzle – Wuzzit Trouble – had already been shown to exhibit promise for learning in other studies (Killi et al. 2015; Pope & Mangram, 2015; Matlen, Atienza, & Fox Cully, 2015), this study's intervention focused solely on exploring the impact and feasibility of the Tiles and Tanks puzzles. We refer to this intervention comprised of these puzzles as the BrainQuake suite, henceforth.

To explore the feasibility and usability of the BrainQuake puzzle suite, as well as to explore the promise of the product for achieving the intended outcomes, WestEd conducted a randomized trial in the fall of 2017 in middle school classrooms (5^{th} and 6^{th} grades). In the randomized trial, teachers were randomly assigned to either use the BrainQuake puzzle suite as a supplement to their mathematics instruction (the treatment condition), or they were to conduct their mathematics instruction in their normal way (referred to as, business as usual; the control condition). This report documents the findings from this study and suggestions for future research and development.

The present work represents an important but early-stage step in understanding how the BrainQuake puzzle suite is used in classroom contexts. The results are valuable in 1) providing initial estimates of the BrainQuake puzzle suite's impact on student outcomes, 2) characterizing its use in a variety of classroom contexts, and 3) providing information about the feasibility and fidelity of the product. The study is conducted with a relatively small sample and the intervention was limited to a relatively short duration, thus, results should be considered within the context of the broader program of research of the BrainQuake puzzle suite. Nevertheless, this study provides a useful and necessary step in understanding how the BrainQuake puzzle suite operates in classroom environments, the results of which can inform future development efforts as well as provide a foundation for a larger program of research. We present the results with these considerations in mind.

Research Questions

The study was guided by the following research questions:

1. How feasible is the BrainQuake suite for classroom implementation?
2. Does the full suite of BrainQuake products show promise for improving students'
   a. Mathematics achievement, and
   b. Students' attitudes toward mathematics?
   c. Is the BrainQuake puzzle suite more effective for certain subgroups of students (e.g., lower vs. higher achieveing students)?
3. What is the impact of the BrainQuake puzzle suite on teachers' pedagogical content knowledge for teaching?

The Study Intervention

The intervention in the present study involved the use of two puzzles: The Tanks puzzle and the Tiles puzzle.

The Tiles puzzle aims to engage students in increasingly complex algebraic thinking. Players manipulate a range of tiles with varying features in order to fill a tray or trays simultaneously by arranging the tiles in the trays and then "growing" them to fill the available space. Features such as UnGrow, see your previous failed solution, and solve for either minimal tile use or minimal grow moves provide BrainQuake's signature varied solution path options.

The Tanks puzzle is designed to facilitate the exploration and understanding of increasingly complex percent, decimal, fraction and non-numerical proportional representations. Players must allocate space in a circular, rectangular, square or radial device in order to distribute a given number of inputs into proportional measures that match the required output distributions. Unlike the Tiles puzzle, however, the Tanks' proportional reasoning puzzle is significantly limited with respect to a rich and varied solution space. This limiting factor is due to the nature of the content, but the interface and puzzles tested as slightly more engaging than the Tiles puzzle in prior usability work.

Both puzzles are driven by their own adaptive engine and are connected to the monitoring and logging system that feeds the BrainQuake scoring algorithm.

The puzzles are meant to be used as a supplement to traditional instruction in mathematics for middle school students. They are designed to engage students in mathematical thinking without the use of traditional mathematical symbols (e.g., equations). Instead, the puzzles use concrete physical representations to instantiate mathematical concepts – the representations can be virtually manipulated (via touchscreen or computer) and therefore engage students in mathematical thinking without the need for symbolic representations of the mathematics, allowing them to explore problems beyond what would be traditionally considered 'grade-level'. Teachers can support students in solving the puzzles, but the puzzles are designed to be played by the students. To explore the feasibility and usability of the BrainQuake puzzle suite, WestEd conducted a randomized trial in the fall of 2017 in middle school classrooms. In the trial, teachers were randomly assigned to either use the BrainQuake puzzle suite as a supplement to their mathematics instruction, or they were to conduct their mathematics instruction in their normal way (referred to as, business as usual).

Treatment teachers were tasked with using the BrainQuake puzzles as a supplement to their mathematics instruction. They were specifically asked to use the puzzles for at least three days a week, for at least 10 minutes each time (though they were allowed to use the puzzles more if they wished). The way in which teachers implemented the puzzles (as homework, warm-up to mathematics lesson, as review, etc.), was intentionally left open, as this allowed the study to explore the variation in how the puzzles are implemented in naturalistic settings. Though the way BrainQuake puzzles were implemented was up to the teachers' discretion, teachers were advised to use the puzzles in an interspersed way – alternating between Tiles and Tanks – as this alternating format was believed to optimally support students' mathematic skills.

Prior to the study, treatment teachers were provided a short one-hour orientation of the puzzle suite. Teachers attended the orientation virtually and the session was recorded for teachers who were unable to attend a live session. The goal of the orientation was to provide an overview of the puzzle suite, demonstrate how the puzzles work, and provide teachers with an oppoortunity to ask questions. BrainQuake staff led the orientation.

Control group teachers were instructed to conduct their mathematics lessons in their standard way, without the use of the BrainQuake puzzle suite.

All teachers were provided a brief video of the study that they could watch at their leisure, which outlined the rationale for the study and oriented teachers to the study tasks. Teachers were randomly assigned to conditions after this study overview.

The study took place over the course of approximately 8 weeks during the fall 2017 semester – the intervention spanning approximately 6 weeks. Both groups of teachers took and administered surveys at the beginning and end of the study. Measures were also collected to document the implementation of the BrainQuake puzzles during the course of the study. Table 1 documents the task timeline over the life of the study. The surveys are described in more detail, below.

Table 1. Study task timeline.

	Week 1 Beginning of Study	Weeks 2- 7 During Study	Week 8 End of Study
Activities conducted In Class to students	- Achievement Assessment -Gears Puzzle - Math Attitudes Survey	- Teacher assigns interspersed puzzle intervention - Classroom observations in subset Treatment classes (one session where BrainQuake game is being used) - Student focus group (one per classroom)	- Achievement Assessment -Gears Puzzle - Math Attitudes Survey - Student Post-Survey
Activities completed by teacher	- Teacher Background Survey - Teacher Math PCK Survey	- Teacher Weekly Logs	- Teacher Post-Survey - Teacher Math PCK Survey - Teacher Interview

Participants

Thirty-four (34) 5th and 6th grade teachers were recruited to participate in the study. Each had teaching experience ranging between 2 and 7 years, and currently teaches at a public elementary school in Northern California. One to three teachers taught at each school participating in the study, with 74% of teachers reporting incorporation of technology in their current classroom practices at least 3 times per week. 71% of the teachers also reported being very comfortable using technology. Among all of the study schools, researchers collected data from 418 5th grade students and 306 6th grade students. Demographic information summarizing the student populations at each participating school appears in Table 2 and information on the teachers participating in the teacher inteviews are summarized in Table 3.

Table 2. Research Study Student Demographic Summary by School

	Sch 1	Sch 2	Sch 3	Sch 4	Sch 5	Sch 6	Sch 7	Sch 8	Sch 9	Sch 10
Total students participating	30	91	93	28	33	NA	34	32	32	NA
Socioeconomically disadvantaged	NA	27%	32%	57%	73%	NA	65%	25%	NA	NA
English learners (EL)	NA	3%	8%	11%	18%	NA	18%	25%	NA	NA
Ethnicity	NA					NA			NA	NA
American Indian		2%	0%	7%	0%		0%	31%		
Asian		1%	0%	0%	0%		0%	44%		
Black		1%	2%	0%	3%		6%	0%		
Hispanic		34%	29%	57%	79%		71%	0%		
Multi-racial		0%	0%	0%	0%		0%	3%		
White		18%	1%	11%	3%		18%	13%		
Not Available	100%	44%	68%	25%	15%	100%	5%	9%	100%	100%

Table 2. Research Study Student Demographic Summary by School (Cont.)

	Sch 11	Sch 12	Sch 13	Sch 14	Sch 15	Sch 16	Sch 17	Sch 18	Sch 19	Sch 20
School size (number of students)	NA	58	32	57	84	NA	34	49	27	27
Socioeconomically disadvantaged	NA	28%	NA	88%	45%	NA	88%	67%	96%	93%
English learners (EL)	NA	5%	NA	40%	14%	NA	47%	29%	63%	56%
Ethnicity	NA		NA			NA				
White		0%		0%	0%		0%	0%	0%	0%
American Indian		0%		0%	0%		0%	0%	0%	0%
Asian		14%		7%	5%		0%	0%	0%	0%
Black		0%		2%	0%		0%	0%	0%	0%
Multi-racial		2%		5%	13%		0%	10%	4%	4%
Hispanic		12%		81%	39%		97%	76%	96%	89%
Pacific Islander		0%		0%	1%		0%	0%	0%	0%
White		60%		5%	6%		0%	10%	0%	0%
Not Available	100%	12%	100%	0%	36%	100%	3%	4%	0%	7%

	Sch 21	Sch 22	Sch 23	Sch 24
School size (number of students)	NA	31	56	30
Socioeconomically disadvantaged	NA	NA	NA	NA
English learners (EL)	NA	NA	NA	NA
Ethnicity	NA	NA	NA	NA
White				
American Indian				
Asian				
Black				
Hispanic				
White				
Not Available	100%	100%	100%	100%

Table 3. Teacher pseudonyms and experience

Pseudonym	Grade Taught	Years Exp. Teaching	Highest Level Education	# Students
LB10	5	7	MA	33
LB09	5	7	MA	28
Sal30	5	6	MA	25
Sal28	5	5	BA	34

Instruments

The following instruments were used to answer the study's research questions:

Student pre/post mathematics achievement

The math achievement assessment was administered at both pre- and post-test and consisted of 16 multiple-choice items and 2 open-ended questions aimed at assessing students' mathematical ability. The achievement assessment was developed by the National Center for Cognition and Mathematics (Davenport et al. 2013). Three of the problems involved understanding number sense and 15 problems involved solving for an unknown quantity using proportional reasoning. This assessment was chosen as the BrainQuake puzzle suite involved practice in these skill areas. Items were derived from Connected Mathematics Project 2 materials and state, national and international standardized tests. Assessment reliability in the present study was .64 at pre and .66 at post. Open-ended items were scored by trained raters using a standardized holistic rubric. Researchers computed weighted kappas to measure inter-rater reliability, which ranged from 0.76 to 0.93. Students were allowed to use scratch paper to compute solutions to the math problems. The survey was estimated to take approximately 30 minutes to complete. The items from the mathematics achievement survey are included in Table 4 of the Appendix.

Student pre/post Wuzzit Trouble assessment

Wuzzit Trouble (referred to henceforth as the Gears Puzzle), BrainQuake's flagship puzzle game, aims to support students' number sense. In the game, mathematical representations are instantiated through mechanical devices that can be physically manipulated. The player solves the puzzle by rotating small gears to turn a large wheel to collect items hanging on the wheel. For a maximum score, the items must all be collected in the fewest number of moves, following the same sequence of logical steps required to solve advanced algebraic problems.

Prior studies have suggested that using these more intuitive representations, students can engage in mathematical problem solving on problems traditionally considered well-beyond their grade-level (e.g., Killi et al. 2015; Pope & Mangram, 2015). However, the Gears Puzzle used as an assessment has been limited. Thus, in the present study, it was used as a pre- and post-assessment. Due to some issues extracting and linking data to subject identifiers, the analysis of the Gears puzzle as an assessment is not described in the present report.

The Gears Puzzle was administered to the students at each assessment for 30 minutes. During this time, the students could progress through the assessment while the adaptive algorithm advanced the levels to meet the student's zone of proximal development. Students were allowed to use the puzzle until the 30-minute time expired. Each student's performance per level in terms of a star score (a categorical rating indicating the number of moves), time elapsed, and level number were recorded.

Students pre/post mathematical attitudes

The students' mathematics attitudes survey consisted of a subset of items from the 2003 Programme for International Student Assessment (PISA) student questionnaire (OECD, 2005). Researchers selected items that were aimed at measuring four constructs: Views towards math, confidence in solving math problems, strategy towards math, and math self-concept. The internal consistency coefficients (Cronbach's alphas) for subscales in the present study ranged from .74 – .87.

The mathematics attitude survey consisted of 4-point Likert items, ranging from Strongly Agree to Strongly Disagree. The only exception to this structure was question 5, related to confidence with mathematics calculations. This 4-point Likert scale question ranged from Very Confident to Not At All Confident. Prior research has suggested that participants overly rely on midpoint responses when they perceive the topic as unimportant (Krosnick & Schuman, 1988). Researchers therefore used a 4-option Likert-scale for all items so that students would not be tempted to overly rely on a neutral response for a topic in which they may have had little personal investment. The overall structure of the student survey is shown in Table 5 of the Appendix, with questions grouped according to each theme.

Classroom observations

Researchers developed an observation protocol that examined how teachers interacted with students as they used the puzzle in class, as well as how teachers linked mathematical concepts from the game into instruction. This protocol further examined whether there were any instances of student persistence, frustration, or methods of completing the suite of games. Trained researchers conducted these classroom observations in a subset of treatment classrooms.

Student focus groups

Researchers asked groups of roughly five to seven students about their perspectives on using the BrainQuake suite of games in the classroom. The focus groups were held during the middle of the implementation period in which students were actively interacting with the BrainQuake suite of games. The students were specifically asked to reflect upon their attitudes and any feedback for improvement regarding the different games in the BrainQuake suite. Students were furthermore asked to reflect upon their ability to persist through challenging or difficult puzzles. These sessions were audio-recorded.

Teacher interviews

Teachers were interviewed upon the completed implementation of the BrainQuake suite of games. The interview protocol asked questions regarding the feasibility of the BrainQuake suite in terms of classroom use, how teachers incorporated the product in the classroom, and their perceptions of their student's experience, engagement, and reactions when interacting with the games. Trained researchers conducted these interviews within a subset of the treatment teachers. Responses to the interview questions were audio-recorded.

Weekly teacher logs

The teacher logs were administered once at the end of each week. The logs asked teachers to describe the course format, any resources used to prepare instruction, and for treatment teachers, BrainQuake implementation details, including the amount of time students were assigned the suite of games and the frequency of assignment. The logs also consisted of open-ended questions about whether teachers believed their students learned from BrainQuake, how engaged students were in playing the game, and any tech issues experienced. Teachers completed the survey online, and each log took approximately 5 minutes to complete.

Teacher pre/post pedagogical content knowledge

Pedagogical Content Knowledge (PCK) is the knowledge of how to teach an academic subject and is engaged during tasks such as planning a lesson, responding to student questions in class, and grading student coursework. The Mathematics Knowledge for Teaching (MKT) measure was used to measure teacher pedagogical content knowledge (Hill, Ball, & Schilling, 2008). Teachers completed portions of the assessment designed to test knowledge related to proportional reasoning in grades 4-8 (Learning Mathematics for Teaching, 2007). This study used the LMT to assess whether teachers' PCK changed across the intervention. The LMT has demonstrated good reliability, ranging from 0.71 to 0.84.

Teacher background questionnaire

The teacher background survey measured prior experience in teaching, educational background, and experience using technology to teach math. This survey consisted of 13 items. The first 6 were multiple choice demographic and educational background questions. Other items asked teachers asked about their years of teaching experience, student grade level and number of students in their target classroom. Another item consisted of a 5-option Likert-style question related to proficiency with operating systems and office tools, and ranged from "No Experience" to "Advanced". The last question related to technology proficiency and the frequency and comfort of using technology in the classroom. This 5-option Likert scale ranged from Strongly Disagree to Strongly Agree and contained a Neither Agree/Disagree option.

Student and Teacher Post-Survey of the BrainQuake suite

The student post-survey consisted of 39 items which assessed students' opinions regarding 1) engagement, 2) usability of BrainQuake games, 3) feasibility of continued use of BrainQuake (e.g., in class, as a learning tool, etc.), 4) perceived ability of BrainQuake to improve student learning and motivation and 5) opinions about their experience with persistence, motivation, resilience and encouragement within each of the three BrainQuake puzzle types (Tanks, Tiles and Gears). Students were asked the extent to which they agreed or disagreed with question statements. Questions related to usability, feasibility, improved learning, motivation and individual puzzle persistence and resilience were on a 5-option Likert scale, ranging from Strongly Disagree to Strongly Agree and containing a Not Sure response. Overall game perception questions were based on a 5-option Likert scale, ranging from Very Hard to Very Easy and contained a Not Too Hard or Easy response. Individual puzzle type questions related to motivation to try again were on a 3-option Likert scale, ranging from Not Very Much to A Lot and contained a Somewhat option. Individual puzzle type questions related to encouragement were provided as 4-option multiple choice items, ranging from Very Discouraged to Motivated To Figure It Out and contained A Little Discouraged and I Wanted to Try Again options. Researchers again used a 4-option multiple choice scale for all items related to encouragement (items 27, 33 and 39) so that students would not be tempted to overly rely on a neutral response. The overall structure of the student survey is shown in Table 6 of the Appendix, with questions grouped according to theme.

The feasibility study teacher post-survey sought to capture teachers' perceptions about BrainQuake games. Like the student survey, the teacher survey asked teachers to agree or disagree with item statements concerning the 1) usability of BrainQuake games, 2) feasibility of continued use of BrainQuake (e.g., in class, as a learning tool, etc.), 3) perceived ability of BrainQuake to improve student learning and motivation and 4) opinions about their students' experience with two of the BrainQuake puzzle types (Tanks vs. Tiles). Teachers were asked 15 questions that corresponded to one of 10 categories (see Table 7 of the Appendix). For the first 8 questions, teachers were provided 5 possible choices: Strongly Agree, Agree, Not Sure, Disagree, and Strongly Disagree. For the 7 remaining questions (items 8-15), teachers were asked to supply their own answer in an open-ended response.

Analysis

Feasibility data

WestEd researchers conducted four focus groups, with approximately 5 to 7 students in each group, four classroom observations, and three teacher interviews. To understand classroom implementation of the BrainQuake games, their feasibility, and the user experience of participants, WestEd researchers reviewed observation and debrief notes, focus group transcripts, interview transcripts, and classroom observation notes to identify major themes and patterns. Guided by Miles and Huberman's (2014) qualitative data analysis process, researchers developed codes based on research questions and emergent themes and then utilized the nVivo software to assist with the analysis of the data.

Student outcome data

Teacher and student post-survey responses were summarized and graphed for comparison between groups and across puzzle types. Students' responses to the mathematical assessment pre- and post- tests were scored and the gains computed by subtracting the students' post-test score from the pre-test score. To statistically examine student gains, paired sample t-tests were conducted on students' pre- and post- test scores, along with standard deviations and Cohen's d effect sizes. The paired t-test and effect sizes allowed for assessment, on average, whether gains differed from zero.

Additional quantitative analyses were conducted to determine the impact of the BrainQuake puzzles on students' mathematics achievement (as measured by the achievement assessment) and students' attitudes towards mathematics (as measured by the attitude survey). To examine the impact of the BrainQuake puzzles on student outcomes (achievement and attitudes), researchers regressed the outcome (either achievement post-test score or the attitudes post-score) on the condition assignment (treatment status), controlling for other student-level characteristics. These regression analyses were conducted using two-level, hierarchical linear models, with a random effect for teachers to account for the nested structure of the design - students within teachers.

Impact modeling was conducted with all students with valid pre- and post-test data (n = 515 in the achievement analysis and n = 415 in the attitude analysis). For each analysis, three models were explored: a condition model, a covariate model, and a moderator model. Because the study was underpowered, we were conservative with including level-two variables, which take away degrees of freedom and therefore can further reduce statistical power. However, in the achievement sample, we included grade as a level two covariate, as descriptive exploration revealed there were slightly more students in 6th grade in the control group. In all models, students' pre-test score (on the achievement or attitudes survey) was included as a level-1 covariate.

Conditional Model. The conditional model (model 1) included fixed effects in the condition model included the condition variable and students' pre-test score. The Condition Model took the following form:

$$\gamma_{ij} = \beta_{00} + \beta_{01}TX_j + \beta_{10}Pre_{ij} + \zeta_{0J} + \epsilon_{I0}$$

Where γ_{ij} is the post-test score for the i-th student of the j-th teacher, TX_j is a dichotomous variable indicating assignment to treatment Pre represents students' pre-test score, and β_{00} is the grand mean of student scores. ϵ_{I0} is a random level-1 error term and ζ_{0J} is the teacher random effect, the variance component of which captures the nesting of students within instructors. Importantly, the main effect of treatment assignment is captured by β_{01}.

Covariate Model. In addition to the condition and pre-test terms in the conditional model, the covariate model (model 2) included student-level fixed effects of students' gender (Female), students' socioeconomic disadvantaged status (SDS; provided by the school district), students' English language learner status (ELL), and the students' scores on the Smarter-Balanced Math section from the previous school year (SB Math; this was not included in the attitude analysis as it was not highly correlated with scores). Covariates were included based on theoretical importance and prior research (they are known to correlate with STEM outcomes), correlational structure, and the representativeness within the dataset (e.g., special education status was not included as a covariate because they were not strongly represented in the present sample).

Moderator Model. The moderator model (model 3) included all variables in the covariate model, but additionally included cross-level interactions between those variables and treatment status. This latter model allowed us to explore moderator effects - whether the BrainQuake puzzles are differentially impactful for subgroups of students (e.g., males vs. females, SDS vs. non-SDS students, etc.).

Findings

RQ 1: How feasible is the BrainQuake suite for classroom implementation?

Classroom Implementation

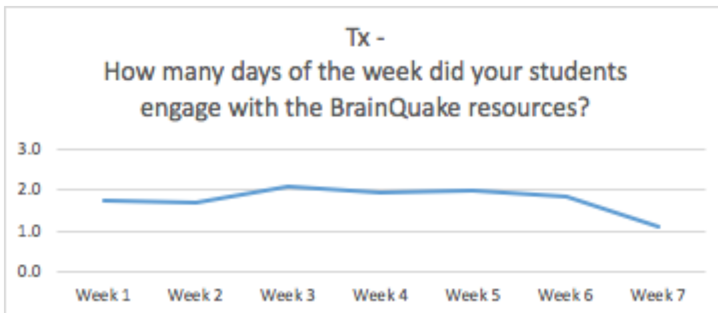
Analysis of the qualitative data provided insight into the methods in which teachers implemented the BrainQuake games in their classroom. The most prominent ways in which teachers implemented BrainQuake included: using the suite of games in conjunction with their math lesson, such as a warm-up or cool down activity, and using the tool as an optional or motivational activity (teachers would use the BrainQuake suite of games as a motivation to finish their classwork). In terms of using BrainQuake to compliment the designated math period, one teacher commented: "[BrainQuake was] used often as a beginning of the day activity when they first came or when done with their must do's and used as a may do."

While teachers would frequently use the suite of games in the methods described above, most of the teachers did not have a consistent way of implementing it on a week-to-week basis. Teachers demonstrated flexibility in the way they implemented the suite. Teachers shared that they could use it as a warm up one week and switch things up the next week and use it as a motivational activity. One teacher spoke to this flexibility, "I used BrainQuake in three different ways. One was when students finished work early, they can use it for a little bit. Other times, there was designated time during the week. Additionally, it was used if there was free time during the week."

Furthermore, a large majority of teachers utilized the BrainQuake games as individual student work. In particular situations, teachers used BrainQuake as group-work and students appeared to enjoy opportunities to engage with the puzzles with their peers. The teacher explained that this enjoyment was further complemented with positive student attitudes, "[students] seemed more positive about their ability to progress because they worked together." This may speak to the BrainQuake puzzles being more difficult for certain classes, and that the tool was beneficial in group settings because the students could collectively work together to find solutions.

Data from the weekly logs examined the frequency that the BrainQuake suite of games was implemented in the classroom setting. Based upon the logs, it was observed that teachers in the treatment condition used the BrainQuake app for roughly two days a week throughout the course of the implementation period. This was consistent throughout most the study (a slight decrease was noticed towards the final week of the study, but this is likely due to implementation of assessments for the study).

Figure 1: Treatment Teachers Used the BrainQuake app on Average 2 days per week



Teachers furthermore provided insight into the amount of time (in minutes) that they spent preparing to use BrainQuake in the classroom. As detailed by the figure below, teachers spent roughly 20 minutes preparing for the implementation of the BrainQuake suite of games (with a large increase to roughly 30 minutes in the second week of implementation). The teacher's 20 minutes of preparation allowed them to fit the suite of games into nearly 450 minutes of math time in the classroom each week.

Figure 2: Treatment Teachers Spent on Average 20 minutes in prep to use the BrainQuake games

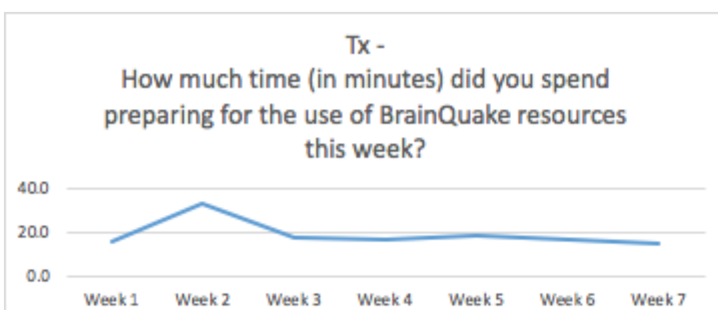
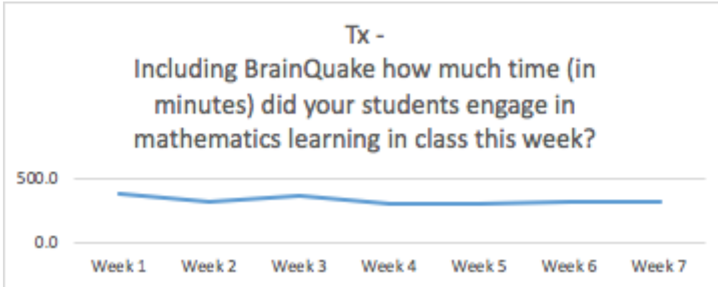


Figure 3: Treatment Classrooms Spent on Average 450 minutes in math time each week



Per the weekly logs, teachers within the control condition reported the educational technology tools that they used each week. The most commonly utilized educational technology tools in the control classrooms were Scootpad, Prodigy, Imagine Math, Khan Academy, and Splash Math. While students were using these educational tools, teachers reported that by in large, the class was overall very engaged. Teachers reflected that a majority of their students were very engaged when using technology in the classroom and typically only a few students got distracted: "Most students enjoy working on the computers and are actively engaged in the math practice and review. A handful of students are less engaged and have a hard time staying focused on what they are supposed to be doing."

Figure 4: Control Teachers Utilized 'Prodigy' and 'Imagine Math' ed tech most commonly in their classrooms

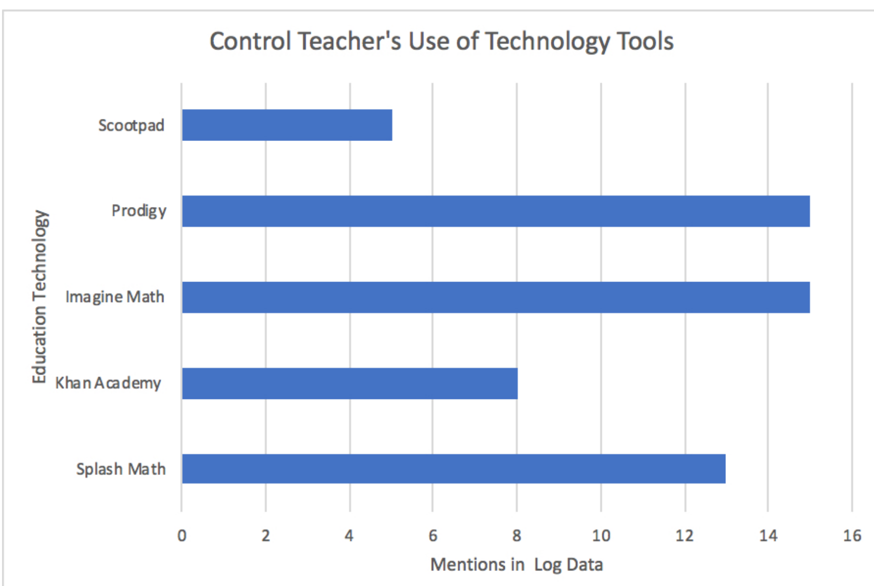


Table 8. Weekly Math Concepts

Week	Most Reported Math Concepts
15-Sep	Ratios
22-Sep	Decimal/Fraction Division
29-Sep	Multiplying Multi-Digits
6-Oct	Multiplication and Division
13-Oct	Fractions (Add, Subtract, Multiply)
20-Oct	Fractions (Add, Subtract, Multiply)
27-Oct	Multiply and Divide Decimals
3-Nov	Rates
10-Nov	Ratios as Fractions/Percents
17-Nov	Distance between Points
1-Dec	Ratios
8-Dec	Ratios

During the implementation period, both treatment and control teachers reported in the weekly logs the specific math concepts that their students were working on each week. Table 8 above describes which concept was most reported within each weekly log. During the implementation period of the BrainQuake suite of games, the most common concepts that were covered in class included working with ratios and manipulating fractions with multiplication, division, subtraction, and addition.

Appropriateness of the Math Content

Most teachers felt the math content was appropriate for their students. However, there were some differences in the perceptions of 5th and 6th grade teachers. Some 5th grade teachers felt that the BrainQuake games may have been too challenging for their students – one explained,

> "It would be nice if the topics covered in your games would be more aligned with what we cover in 5th grade. There is a lot of work with percentages, decimals and fractions. The beginning of 5th grade may not be the time to use this game... perhaps more toward the end of the year."

Additionally, another teacher was able touch upon the deviation between 5th grade content knowledge and the abstract nature of the BrainQuake suite.

> "The Gears puzzle would be perfect for mental math calculation. Proportions are too difficult for most 5th graders as we have not even reached our unit on fractions yet. Even

> though they have had fraction work in previous grades, they are still struggling with understanding fractional parts on a more abstract level."

This teacher's quote highlights that students may have some experience with the content on a surface level, but they may not be as equipped to abstractly interact with these math concepts. Overall, the BrainQuake suite was outside of the ability of 5th grade students, but it is important to note, as evidenced by these quotes, that these teachers were still able to foresee the promise that this platform may possess when presented at the appropriate time in their curriculum. Both teachers emphasize that the BrainQuake suite could be a valuable tool when paired with aligned content, and one teacher further notes that the Gears Puzzle, which they perceive to be at an appropriate level, is a beneficial resource.

On the other hand, 6th grade teachers felt that the content of the BrainQuake puzzles were appropriate for their students. These teachers reflected that their students were comfortable with the math concepts expressed in the BrainQuake puzzles. One 6th grade teacher explained, "I liked how it approached teaching math concepts in a different way, such as the fraction games. Kids seemed to have fun while they played… The puzzles seemed to challenge most students but the concepts were familiar." Another 6th grade teacher had a similar perspective and reflected that, "I liked that [BrainQuake] felt like a game for the students and it provided an engaging, visual representation of the mathematics. [It provides in] an alternative fashion what we normally present to students." The feedback provided by 6th grade teachers speaks to the enjoyment that both students and teachers had when interacting with the BrainQuake suite.

The BrainQuake suite was perceived by 6th grade teachers as an appropriate challenge and tool for students because it aligned well with concepts in which the students were already familiar. Additionally, it provided an avenue for students to learn and interact with mathematics from a different perspective than the traditional classroom approach. One teacher remarked upon this opportunity, by highlighting the benefits of accessing different methods of teaching concepts through the integration of the BrainQuake suite.

> "With my math instruction, I try different ways to access the math; This program helped students learn different ways to understand ratios and percentages from my normal instruction; by doing so they are able to strengthen their understanding of the concepts; I

always try to teach with different formats to support learning; I usually teach 3-5 different formats; It allows students to see the same concepts in different ways."

Through the implementation of the BrainQuake suite, this teacher was able to use the game as a tool to successfully introduce an already familiar content area in a new and abstract manner, strengthening their working knowledge of the subject. Ultimately, the differences observed between the experiences of 5th and 6th grade classrooms, the BrainQuake suite was most successfully implemented -- from the perspective of the teachers -- in the classrooms in which students were already familiar with the content.

Classroom Feasibility

The teacher training was holistically viewed as "a good preview of what to expect" and it was fundamental for providing information about the basics of implementing the BrainQuake suite of games. Reflecting upon this training further, teachers felt that it could be additionally beneficial if there were similar videos available for the teacher to introduce the game to the students. Some of the teachers further identified that including details on how each of the puzzles corresponds to state standards would help them incorporate the tool into their daily curriculum.

Throughout the implementation of the BrainQuake suite of games, there was a range in the available technology across classrooms. By in large, the platform was implemented using Chromebooks or PC laptops, but there were some outlying classrooms that accessed the platform through IBM desktops (three classrooms) in a computer lab or iPads (two classrooms). The extent of accessible technology further corresponded to the teacher's ability to set up and use the BrainQuake suite of games.

Overall, a majority of teachers reported that the BrainQuake suite was difficult to set up and use in the classroom due to the reoccurring technology challenges. One teacher reflected upon their experience using the BrainQuake suite in their classroom, commenting, "Not being able to log in easily or the puzzles not loading quickly enough made using these puzzles frustrating at times. The logistics of getting the Chromebooks out of the storage room and coordinating use time with the other teacher was a bit of a hassle." An additional teacher reported on the antiquated technology available to his students, "Our hardware was very old. We have desktops, not laptops. They were the old IBM clones, pizza box style desktops. Clearing the cache did not help fix problems on these machines." These glimpses into the teacher's access to technology and subsequent difficulties implementing the platform highlight an important trend represented by a majority of teachers. Classrooms without the latest technology or access to immediate technical support, faced challenges in accessing and navigating through the BrainQuake suite of games. As this reflection from a teacher showcased, these technological issues were often times compounded with teachers having to logistically reorganize times in which they could access the school's limited technology, making it more challenging to set up and use the BrainQuake suite of games.

It is important to note that a handful of teachers that had access to newer technology were able to integrate the BrainQuake suite with ease. One teacher commented, "No [we did not experience any technological difficulties], our school district is all caught up with technology. We have a whole tech team and our internet is really good. We could play whenever we wanted." Only a small segment of the participating teachers reported that they experienced minimal issues with access and set-up and it seemingly varied as a result of the class's availability to technology and immediate support. Overall, issues with technology were persistent throughout the course of the implementation period. Within the treatment condition of logs that provided a response, 75% of teachers experienced some sort of technical difficulty while implementing the game in their classroom (62/(62 + 21)). This is in contrast to 9% of teachers within the control condition that experienced no technical difficulties when using different technology tools in their classroom(5/(5 + 49)).

Figure 5: 72% of Treatment Teachers Experienced Technical Difficulties While Implementing BrainQuake Resources

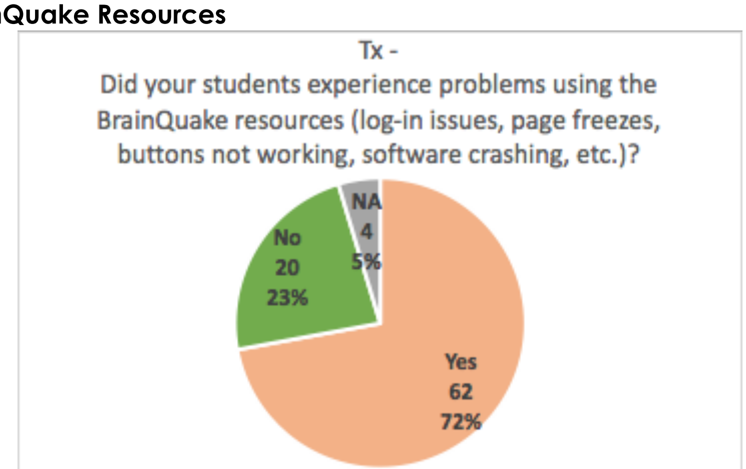
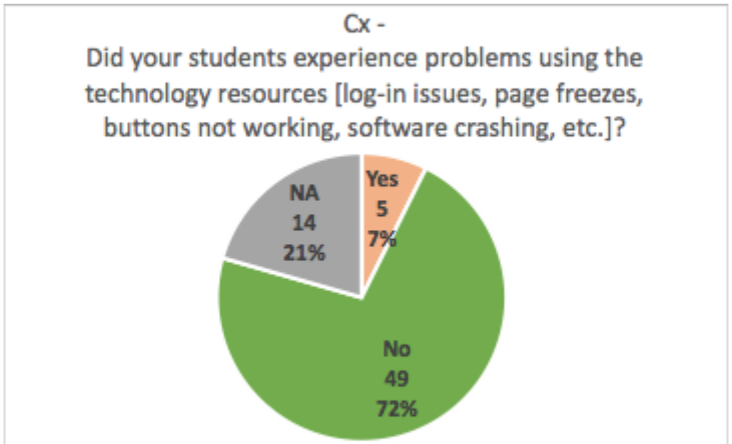
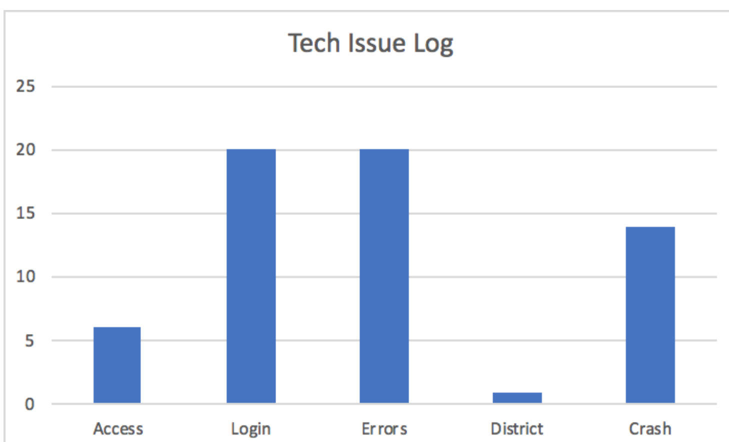


Figure 6: 72% of Control Teachers Experienced No Technical Difficulties While Implementing Technology Tools



The occurrences of technological issues (as shown in the Figure 7 below) were recorded over the length of the study and were apparent every week of the implementation. Teachers primarily ran into difficulties accessing the World Map or Gears Puzzle game series, logging into the platform, receiving app error messages, instances of the school district blocking access, and experiencing game freezes or crashes during student play.

Figure 7: The Most Commonly Experienced Technological Issues in Treatment Classrooms were App Error messages and Logging Into the Platform



The collection of difficulties within the classroom was troubling for teachers and as a result many did not feel comfortable implementing the BrainQuake game suite most weeks. Some teachers added that it may have taken away from the student's enjoyment of the product; "Two students couldn't log in. We got that resolved by changing their log in. Students that reached the World Map really enjoyed it, but most of my students were stuck on the Gears. When the computer would freeze, it would start them again. They were very frustrated and ready to move on." Even though students were periodically confronted with issues when navigating through the suite of games, this quote also touches upon the positive views from students that were able to access the puzzles. When the BrainQuake suite was working, the teacher observed positive student feedback toward their experience interacting with the puzzles.

Student Engagement

Students were generally able to successfully use the BrainQuake suite of games. Figure 8 shows 56% of students found the product easy to use, indicating that they agreed that "when using BrainQuake puzzles, they knew what to do without anyone telling them". The majority (60%) of post-survey student respondents thought that most kids would learn how to use BrainQuake puzzles easily. However, some students experienced challenges during gameplay: 41% of student post-survey respondents thought that playing BrainQuake puzzles was confusing.

Figure 8: 56% of Student Post-Survey Respondents Found BrainQuake Easy to Use

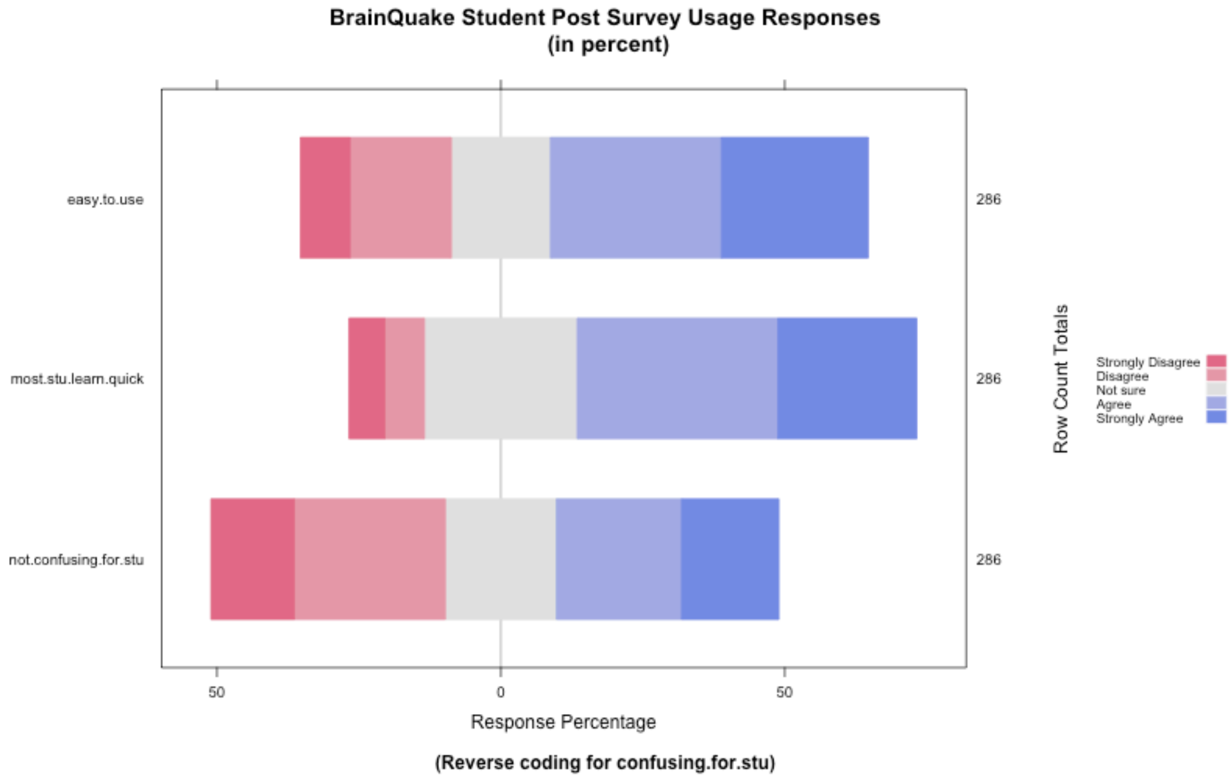
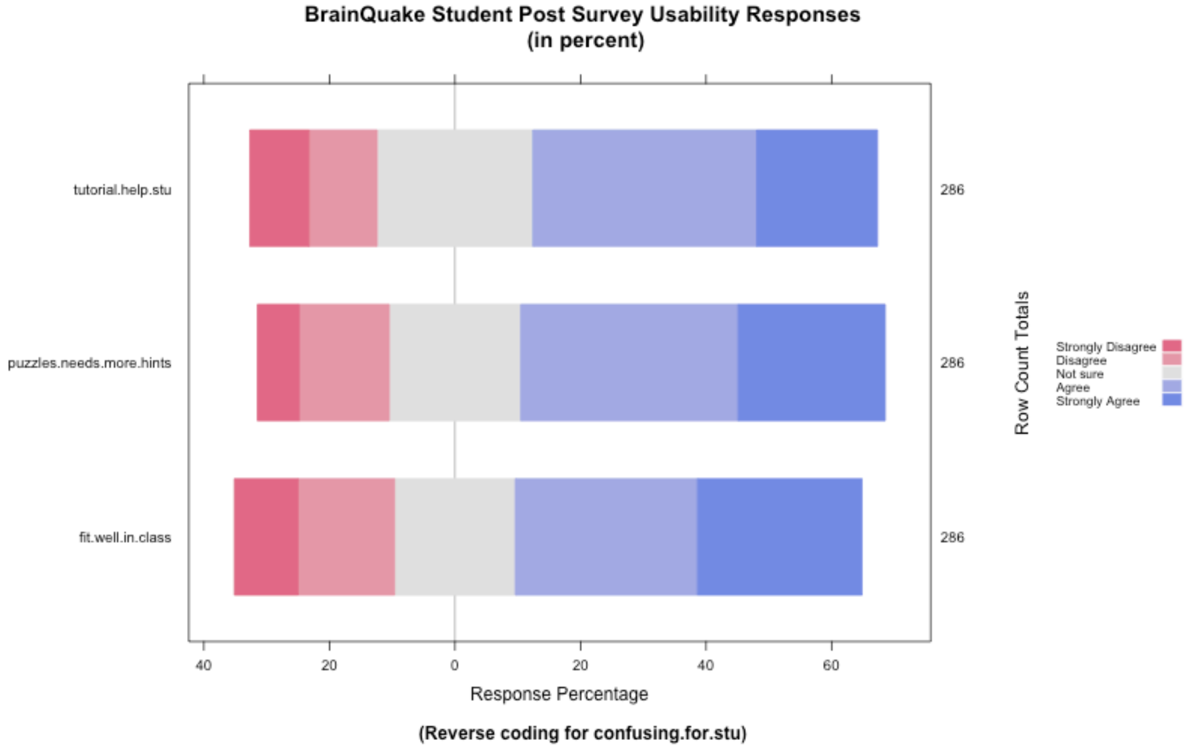


Figure 9 indicates that while most students (55%) found existing tutorials helpful, 58% reported that BrainQuake should provide more hints or directions. Overall, 55% of student respondents agreed that BrainQuake puzzles fit well in their classroom activities.

Figure 9: 55% of Student Post-Survey Respondents Agreed that BrainQuake Puzzles Fit Well in Their Classroom

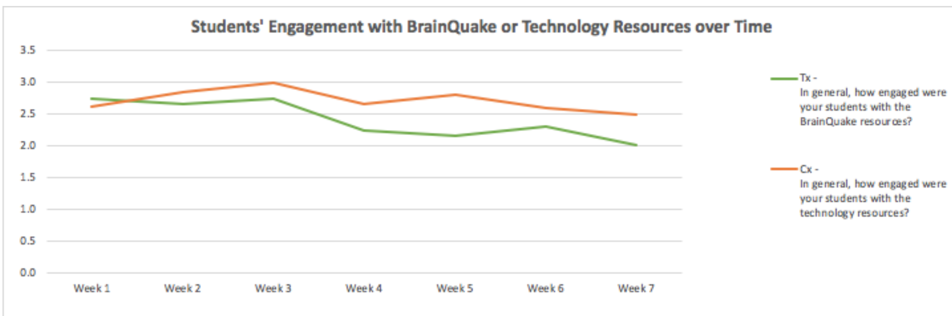


Researchers further observed student engagement strengths and challenges in the classroom. When students could successfully interact with the BrainQuake puzzles, they were engaged and focused on working through and solving the different puzzles. Students commented that they thought the BrainQuake suite was highly engaging and enjoyable. *This was consistent even in cases where the puzzles were becoming harder to solve.* "When students would solve a puzzle they would throw their arms up in excitement. They would also exclaim 'ahhhhh' [in a slightly disappointed way] when they would get the question wrong." Students' persistence at solving puzzles, even in the face of failure, continues to be a consistent characteristic of the BrainQuake puzzles.

Teachers further observed that students were very excited to interact with the games, particularly at the beginning of the implementation. One teachers' students enjoyed their experience working through the BrainQuake suite so much that it became a tool for this teacher to motivate them to finish their other classwork, "it motivated them to get their work done, because they wanted to play the game." Teachers additionally commented on not only the enjoyment shared by their class, but the ease in which they were able to figure out how to interact with the new puzzles. "Once all the login issues were solved, the students were happy to move to the Tiles and Tanks puzzles. Students quickly figured out how to manipulate both puzzles and solved the first few levels."

Other teachers experienced this same level of enjoyment from their students, but as time progressed throughout the study, there was a decrease in the level of student engagement that teachers reported (as seen in Figure 10).

Figure 10: Treatment Students Experienced a Larger Decrease in Engagement vs. Control Students After 7 Weeks

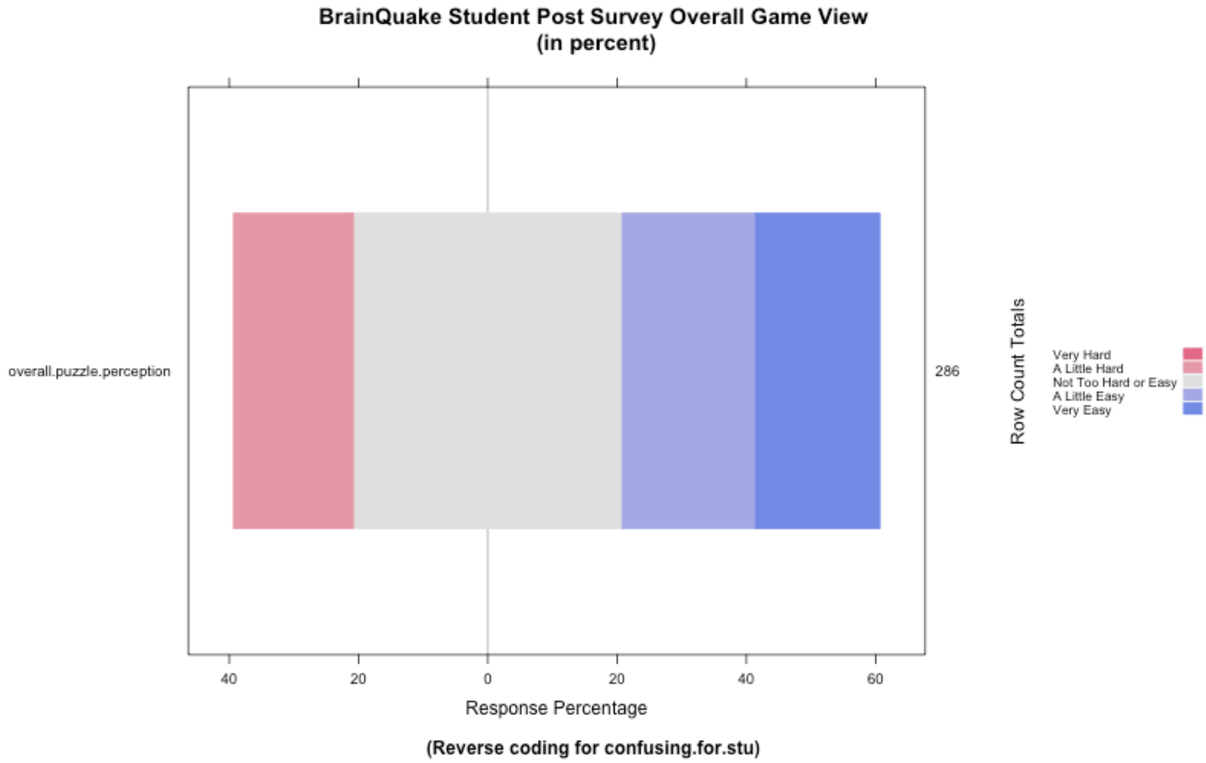


As depicted by Figure 10, students in the treatment condition experienced a larger decrease in engagement as perceived by the teacher than the control group. Teachers within the control condition experienced a steady rate of student engagement while their students interacted with different technology resources. The decline experienced by the treatment condition could be due to the increase in technical difficulties toward the end of the implementation period (including students being unable to progress forward through the puzzles). The technical issues students experienced when playing the games, was a point of frustration. "The students were on task; however, they were frustrated/anxious/disappointed when they ran into software problems."

Overall Student and Teacher Perceptions of BrainQuake Suite

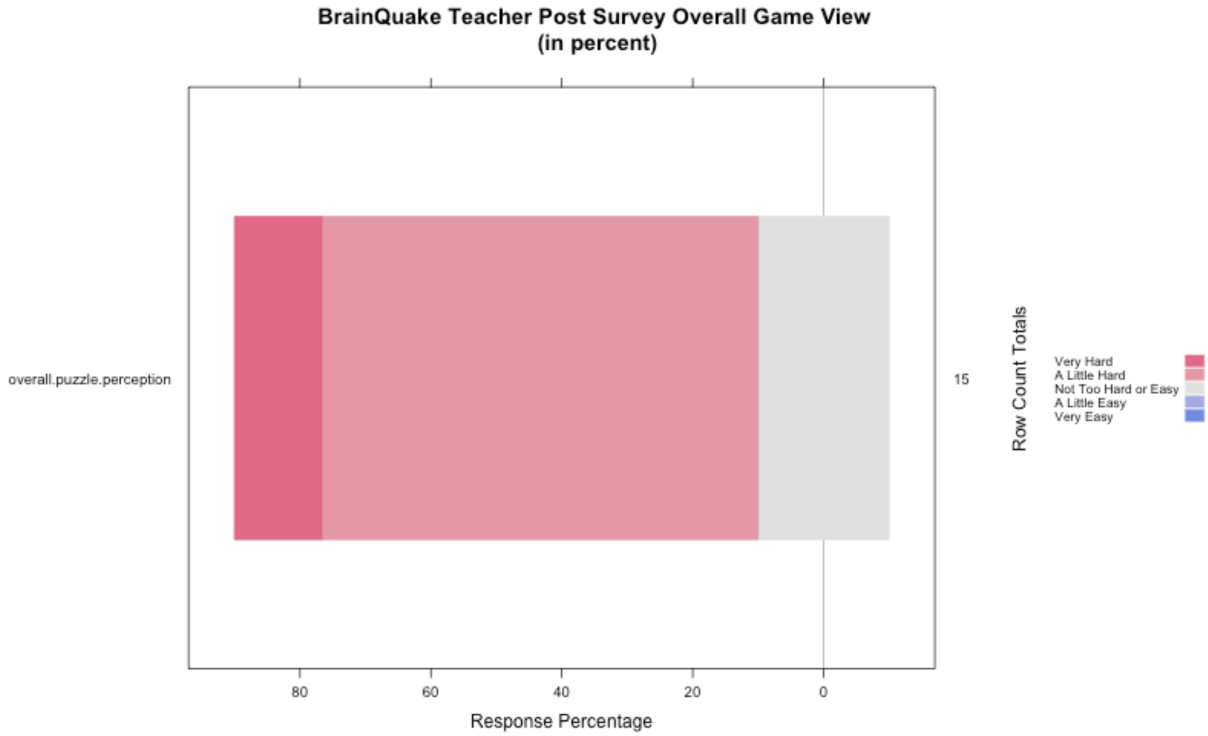
Student and teacher respondents differed on their perceptions of student difficulty regarding the BrainQuake suite of games. Figure 11 show 40% of student post-survey respondents felt that the games were 'very easy' or 'a little easy'. 42% had a "just right" response, describing the games as 'not too hard or easy'. While 18% described the games as 'a little hard', 0% of students characterized the games as 'very hard'.

Figure 11: 40% of Student Post-Survey Respondents felt that the BrainQuake Suite of Games Were 'Very Easy' or 'A Little Easy'



In contrast, teacher post-survey responses indicated that teachers thought the games were challenging for their students (see Figure 12). No teachers responded that the games were 'very easy' or 'a little easy' for the students. 20% described the games as 'not too hard or easy'. 67% described the games as 'a little hard' and 13% of teachers characterized the games as 'very hard' for their students.

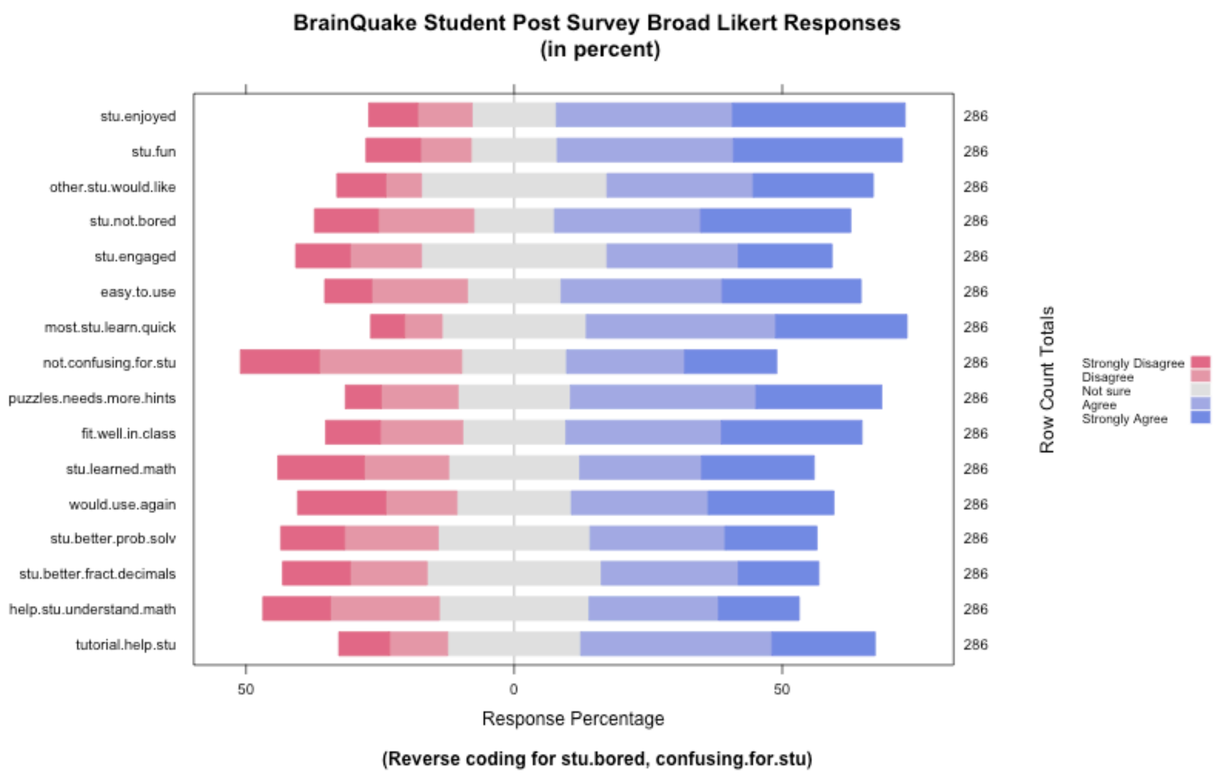
Figure 12: 67% of Teacher Post-Survey Respondents described the BrainQuake Suite as 'A Little Hard' for Their Students



This contrast between student and teacher perceptions may be indicative of the two groups' perceptions of game play. The teachers were evaluating the students' ability to perform the math. The students were less focused on the mechanics of mathematics and instead were engaged by the gamification of the platform. The students may have been immersed in the excitement of the contest, and less aware of the struggle to learn the corresponding mathematics.

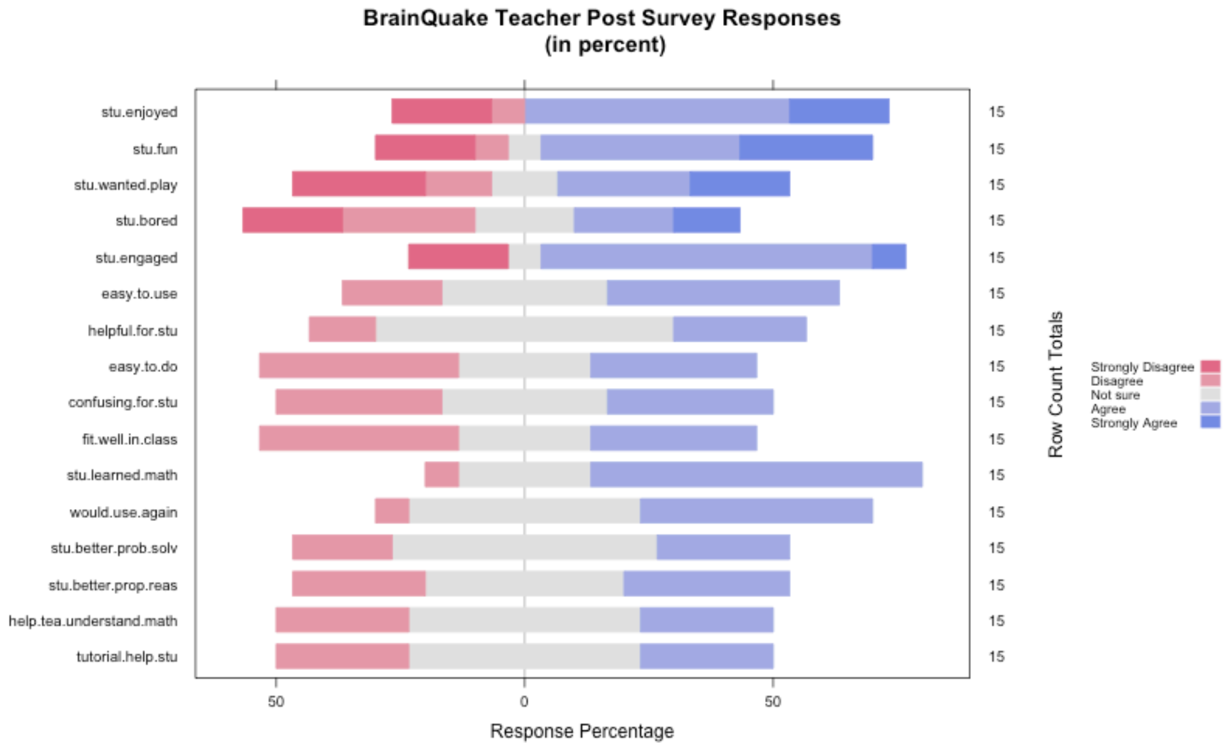
Figure 13 shows that 65% of the students reported enjoying the BrainQuake games, and 64% indicated that the puzzles were fun. Many students (50%) felt that other students their age would like the BrainQuake puzzles and 55% did not experience boredom while playing the games.

Figure 13: 65% of Student Post-Survey Respondents Reported Enjoying the BrainQuake Suite of Games



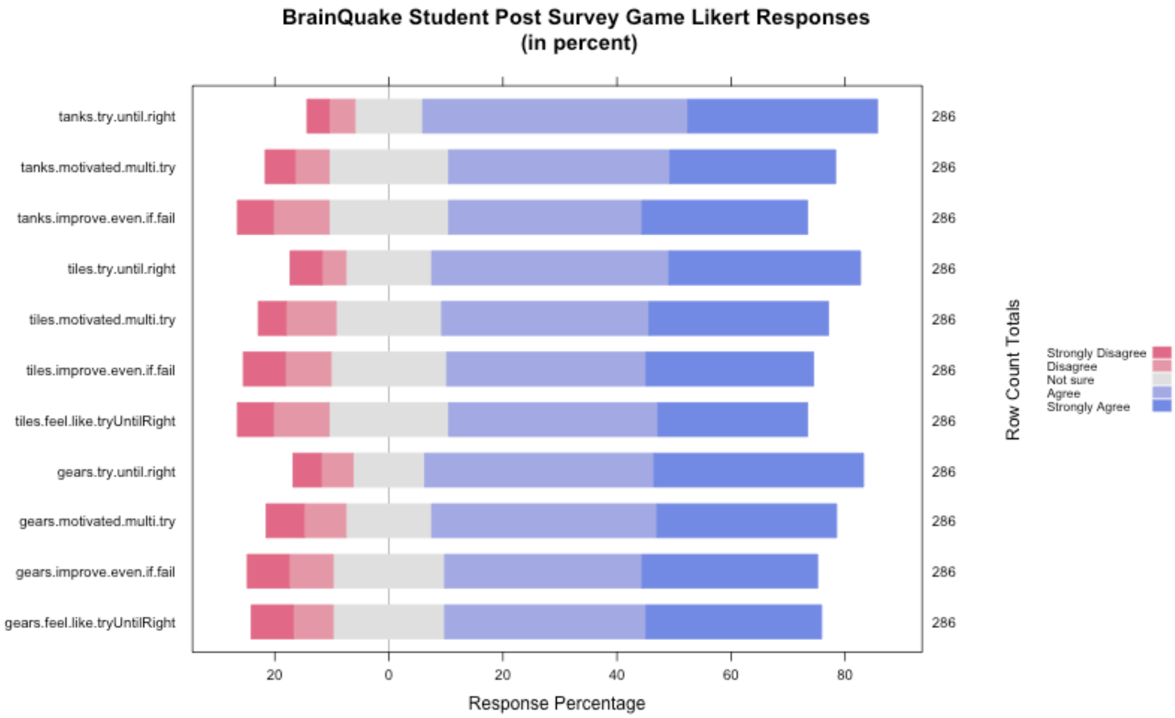
This perspective may be confirmed by the teacher's perception that the students found the engagement with mathematics in the BrainQuake games to be pleasant. Figure 14 displays that 73% of the teachers reported that they thought the students enjoyed the BrainQuake games, and 67% indicated that they thought the students had fun using BrainQuake puzzles. Many teachers (47%) reported that the students wanted to play the BrainQuake games even without the teacher telling them to; 33% reported that student were not bored, and 73% indicated students were engaged while playing the puzzles.

Figure 14: 73% of Teacher Post-Survey Respondents Reported That Their Students Enjoyed the BrainQuake Suite of Games



When asked to contrast the three game types specifically, student post-survey respondents indicated an equal desirability for each game, with only a slight preference expressed toward the Gears puzzle. When asked would they keep attempting the puzzle until they got it right, students expressed agreement evenly among the three puzzles, Tanks, Tiles and Gears (80%, 75%, and 77%, respectively). Positive response rates remained high when students were asked if they were motived to try a different way or if they failed at first, did they feel there were chances to improve or learn (68%, 68%, 71%, and 63%, 64%, 65%, respectively).

Figure 15: 75%- 80% of Student Post-Survey Respondents Would Keep Attempting Each Type of BrainQuake Puzzle Until They Got It Right



In the qualitative section of the survey, teachers were asked about observed differences in students' experiences (e.g., enjoyment, engagement, challenge, etc.). When playing the Tiles game compared to the Tanks game, the majority of teacher post-survey respondents (60%) indicated no difference in student experiences between the two games. 20% of teacher respondents indicated that they thought students enjoyed or had less technical difficulties with the Tanks game. One teacher felt, "[Students] used more strategy when using the Tiles game. The Tanks game allowed for more trial and error and was difficult to make the connection to the [mathematical] values". 13% of teachers had no response regarding differences between students' experiences with the Tiles and Tanks games.

Student and Teacher Perceptions of the Tiles Game

Students overall enjoyed the Tiles game. From the discussions in the student focus groups, students did agree that the tiles game was difficult, "It gets super hard. I thought it was kind of hard, kind of difficult. It was hard to understand how to put the tiles right" but they also felt that the Tiles game was an enjoyable challenge. "I liked all of it." "It gets hard and you like struggle with it…that was a good thing." There was a common theme that these games presented a challenging math experience for students.

Teachers had feedback on the Tiles game, but overall thought it was useful. In a teacher interview one participant remarked, "They could understand it more. They could visually see the bar move or increase on the screen." This teacher appreciated the visual aspects of the game and found this feature to be an integral mechanism for student understanding. In contrast, a different teacher proposed that some students may need more scaffolding when solving the Tiles games. This teacher responded saying:

> "Tiles didn't give you any information on how to do it; not intuitive to use tiles; some students took longer to understand how to play and others figured it out right away. Just like math concepts, some looked at the instructions; others were not able to access the instructions. [It was a] mixed bag. Some thought it was easy and some thought it was hard; [It was that way with] every student. Some thought it was hard, some thought it was easy."

Like learning math concepts, students were learning how to apply mathematics to this suite of puzzles while learning how the puzzles themselves operate. This teacher touched upon the complexity of meeting students at their "zone of proximal development" and how the Tiles puzzle may be too difficult initially to meet all student's needs.

Student and Teacher Perceptions of the Gears Game

By majority, observed students were the most engaged and expressed the most enjoyment when playing the Gears puzzle. During a classroom observation, students were notably excited to speak about the different characters (Wuzzits) that were in the Gears puzzle. The feature of having more of an objective (solving the puzzle to free the Wuzzit) was something that got the students' attention.

Furthermore, students spoke to the fact that within this puzzle they were able to solve the puzzles in different ways. One student expressed that they like having numerous ways to solve an answer because, "… that is how we are learning and we have to learn different ways of math, of how to do it. Cause there's different ways to get different answers, well, the same answer." The Gears puzzle allowed students to creatively navigate through the levels which was seen as a positive experience for many students. This student was additionally able to make the connection after playing the Gears puzzles that they are learning different ways to do the same math when they can solve the puzzle in different ways.

Teachers agreed that the students enjoyed the Gears puzzle and it was perceived to be a beneficial and enjoyable suite of puzzles for their students. One teacher remarked that, "I would love to see the Gears puzzle become a regular app that students could use and access." This teacher, like many others, thought that the Gears puzzle would incorporate well into their classrooms as a regular feature. Another teacher spoke more to this point and found that it was appropriate for their class. They reflected that, "Using Gears was fun and a good level of problem solving for 5th graders."

Student and Teacher Perceptions of the Tanks Games

Similar to the student impressions of the Tiles game, the Tanks game also had mostly positive reviews from students. Students enjoyed the challenging aspect of the Tanks game and remarked that they, "Prefer the Tanks game because the Tanks game is just challenging. Like they said, it's more challenging and the Tiles one is just a little too easy."

Collectively students liked the aesthetics of the Tanks game and that the visuals made it a fun experience. One student group responded excitedly, "OH those are fun! I love the sparks, the bubbles, and the fill button. I like the background!" Overall, the background and animation of the Tanks puzzles made it an entertaining platform to solve math puzzles.

Teachers evidenced a mix of perceptions of the Tanks games. Some teachers expressed that it was too difficult for their students and that it was their least favorite of the puzzles while other teachers reflected that it presented a positive challenge. One teacher reflected upon the benefits they felt their students gained upon interacting with these puzzles; "Tanks felt like math and they thought it was good. [It] made them feel better about math and their ability to do math. [They] feel more confident about math and not as negative about math." This quote in a way reflects the characteristic design feature in all of BrainQuake puzzles – an interface that allows you to engage in math problems in a challenging but safe way (i.e., without risk of negative motivational consequences of failure).

RQ 2: Does the BrainQuake suite show promise for improving students' mathematics achievement and students' attitudes toward mathematics?

Throughout this section, we report statistical analyses of content assessment data. 603 students responded to the pre-test assessment and 531 students completed the post-test assessment. Of the post-assessment respondents, 28 students had a corresponding pre-assessment, leaving 503 students that completed both a pre- and post-assessment for comparison analysis.

We examine overall gains from pre-test to post-test, first with all students that completed a pre- and post-test, and then with low SES students. There were 243 students represented in the control group, and 260 students in the treatment group. As displayed in Table 9 below, there are statistically significant differences, at a 0.05 significance level, in pre-test to post-test scores for both the control and treatment groups. Results show that post-tests increase for the control group, as well as for the treatment group after exposure to the treatment.

What do these statistics mean?

Two important statistics are p-values and effect sizes.

P-values give information about the precision of the statistical analyses. Lower p-values are representative of higher precision, and would indicate a higher likelihood that the differences are statistically different from zero, if there was truly no difference. The standard convention in education research is to consider p-values smaller than .05 to be statistically different from zero.

Effect sizes (reported as Cohen's *d*) represent the magnitude of the statistical effects. Effect sizes represent the change from pre- to post-test, in units of standard deviations. Effect sizes below .25 are considered small, but could be still educationally meaningful. Those above .25 are considered substantive for education (e.g., What Works Clearinghouse, 2017).

Table 9. Quantitative Pre-test and Post-test Scores (Means, Standard Deviations and Cohen's d Effect Size of the Difference) for both condition groups

Condition	N	Pre-test Mean, SD	Post-test Mean, SD	Gain	95% CI for Mean Diff.	*t*-Statistic	*p*-Value	*Effect size*
Control	243	5.13, 2.72	5.57, 2.98	0.44	-0.81, -0.07	-2.37	0.02	0.15
Treatment	260	4.97, 2.68	5.34, 2.86	0.37	-0.70, -0.04	-2.23	0.03	0.14

Baseline Equivalence

Prior to conducting the impact analysis, we examined the equivalence of the groups prior to the intervention (i.e., referred to as "at baseline") to determine if the analytic sample of students was similar prior to the start of the study. To do this, pre-intervention variables were regressed onto the condition variable, accounting for the nested structure of the design. Table 10 reports the effect sizes, coefficients, and p-values of these analyses for each pre-intervention variable.

Table 10. Baseline equivalence statistics. Continuous variable effect sizes are reported in Hedges' g whereas dichotomous variable effect sizes are reported in relation to the Cox index.

Variable	Achievement Sample			Attitude Sample		
	Effect Size	*Coef*	*p*	*Effect Size*	*Coef*	*p*
PreTest	0.08	0.24	0.73	0.00	0.00	0.99
SB Math	-0.01	-1.28	0.97	-0.05	-4.37	0.89
Female	0.24	1.49	0.07	0.05	1.08	0.76
ELL	0.07	1.12	0.86	0.08	1.15	0.84
SDS	-0.64	0.35	0.22	-0.58	0.39	0.27

Effect sizes correspond to standard deviation differences in the treatment vs. the control group prior to the intervention. For the most part, the groups do not differ statistically on any baseline variables across the samples, and effect sizes are mostly below .25 and above -.25. The exception is the SDS – there are more SDS students in the control relative to the treatment. Thus, we attempt to control for SDS by including it as a covariate in the impact analyses, reported below.

Impact on Achievement

The output from the models of student achievement are presented in Table 11. The models attempt to address the question: After attempting to control for student pre-test scores (and in some cases, other baseline variables), what is the impact of the BrainQuake suite on students' mathematics knowledge? Put another way, we are interested in what a control students' mathematics achievement would be if his/her instructor, in an alternative universe, were assigned to the treatment group. Because students cannot participate to both conditions simultaneously, our randomized trial is a proxy for this counterfactual scenario.

Table 11. Achievement modeling output.

Variables	Condition Model			Covariate Model			Moderator Model		
	Coef	*SE*	*p*	*Coef*	*SE*	*p*	*Coef*	*SE*	*p*
Intercept	5.94	0.35	0.00	6.42	0.59	0.00	6.06	0.83	0.00
Condition	0.24	0.40	0.56	0.03	0.49	0.95	0.49	1.04	0.64
PreTest	0.48	0.04	0.00	0.29	0.05	0.00	0.16	0.09	0.07
Female				-0.05	0.28	0.85	-0.63	0.44	0.15
sds				0.22	0.38	0.56	0.54	0.63	0.39
ELL				-0.12	0.36	0.74	0.01	0.56	0.98
SB.Math				0.02	0.00	0.00	0.02	0.00	0.00
Grade	1.83	0.41	0.00	1.03	0.50	0.06	1.52	0.86	0.10
Condition* PreTest							0.20	0.11	0.07
Condition* Female							0.86	0.57	0.13
Condition* sds							-0.50	0.79	0.53
Condition* ELL							-0.21	0.74	0.78
Condition* SB.Math							-0.01	0.00	0.13
Condition* Grade							-0.75	1.09	0.50
Condition Effect Size (hedges g)	0.07			0.01			0.15		

The central variable of interest in the models is the Condition variable. For this variable, positive coefficients indicate higher post-test scores for treatment students. The condition coefficient can be interpreted as the average difference in post-test achievement scores in the treatment relative to the control condition, given that the groups were equivalent prior to the intervention.

In all models, the estimate of in the condition variable is positive – indicating greater post-test achievement in the treatment relative to the control group – but not at a statistically significant rate and at small effect sizes. For example, in the Conditional Model, the effect is positive even when controlling for pre-test and grade .24 question improvement in the post-score (however, the treatment effect is not "statistically significant" i.e., a p-value of < .05). The effect size is small at .07.

The third model explores moderation effects – that is, are the BrainQuake puzzles more impactful for different subgroups of students? This question was explored by including interactions in the models between the treatment variable and the baseline variable of interest. The variable that produced a marginal moderation effect was students' pre-test score. The coefficient for this model suggests that the treatment was more beneficial for students' performing higher on the pre-test assessment (i.e., for every 1 point improvement on the pre-test score, there is a 0.20-point advantage, on average, for the treatment relative to the control group on the post-test).

Analysis of the qualitative data show students were able to access math in a way different from their regular instruction, "BrainQuake was a fun break from direct instruction. It allowed my students to learn math concepts without fear of graded material or negative feedback from a teacher". Teachers appreciated how BrainQuake allowed students to engage with math without even realizing it.

Due to the timing of the study not being aligned to the proportionality and ratio section of the math curriculum, 5th grade teachers had difficulty reporting the math skills students learned from using BrainQuake. When asked did the students learn math from using BrainQuake, one 5th grade teacher responded, "I hope so. [We] will gauge later when they get to those concepts in the math curriculum. I'll see if this class is able to pick up those concepts faster than other classes".

In contrast, the 6th grade teachers reported several math related benefits of the games on students' mathematical understanding of proportions and fractions and ease and speed of completing math problems. Below is a sample of teacher responses about student learning:

- "They seem to be understanding proportions better."
- "I believe they are getting a better understanding of how fractions work. The variety of questions is a plus."
- "It helped reinforce some of the concepts we are learning in class.
- "They think some math is easy now."
- "The students are getting quicker at solving the puzzles, especially the Tanks games. A few have started to see a correlation between the size of the main Tank and the volume of the fill tubes."

One teacher reported the game-based learning environment of BrainQuake did not offer her students an effective learning opportunity. "I think they learned very little. I felt like it was more of a game. If there was something that could offer hints or feedback, [like] help videos or short mini-lessons. They didn't improve much. There was nothing there teaching them or showing them ways to solve different problems." This quote may reflect the need for digital manipulatives, in order to bridge the puzzles with traditional mathematical symbols, which are inevitably how students will be assessed.

To improve student learning, several teachers suggested the BrainQuake suite of games be explicitly aligned to Common Core State Standards, so the games can be readily incorporated into their math curriculum. Providing direct connections between the BrainQuake suite of games and the math curriculum through digital manipulatives can allow for better alignment with traditional math assessments of student learning. Overall teachers reported the greatest advantage of utilizing the games in the classroom was not student gains in mathematics but the overall excitement about math generated by the BrainQuake games.

Impact on Student Attitudes

To examine impact of the BrainQuake puzzles on students' attitudes towards mathematics, student responses to the attitude survey were converted to a number (with –2 corresponding to a strong negative response, 2 corresponding to a strong positive response, and 0 representing a neutral response). Students' responses were then averaged across the survey. The hierarchical models used in the above impact analysis on achievement were also used to examine impact on attitudes – Table 12 shows the results.

Table 12. Attitudes modeling output.

Variables	Condition Model			Covariate Model			Moderator Model		
	Coef	*SE*	*p*	*Coef*	*SE*	*p*	*Coef*	*SE*	*p*
Intercept	0.51	0.04	0	0.52	0.08	0	0.38	0.11	0
Condition	0.05	0.06	0.39	0.07	0.07	0.36	0.27	0.14	0.05
PreTest	0.75	0.04	0	0.71	0.05	0	0.79	0.09	0
Female				-0.11	0.06	0.06	-0.01	0.09	0.88
SDS				0.01	0.07	0.87	0.14	0.11	0.21
ELL				-0.01	0.07	0.91	-0.05	0.12	0.67
Condition* PreTest							-0.13	0.11	0.24
Condition* Female							-0.16	0.12	0.18
Condition* SDS							-0.2	0.14	0.17
Condition* ELL							0.07	0.15	0.64
Condition Effect Size (hedges g)	0.08			0.12			0.45		

As in the achievement outcomes, the impact of the BrainQuake puzzles on attitudes are consistently positive, in favor of the treatment in all models, indicating that the math attitudes in the treatment condition are more positive at post-test than those of the control condition. The estimates are not statistically significant, except in the moderator model, where the effect trends towards statistical significance. Effect sizes are overall small but positive - the small effects are to be expected given the short duration of the study. In the moderator case, the effect is of a substantial size.

To further explore BrainQuake's impact on students' math attitudes, we broke down the analysis of the attitudes by the survey's four subscales. We then modeled the gain in the scores, predicted by the treatment variable and pre-test score, with a random effect for teacher. The results of the subscale analyses are presented in Table 13.

Table 13. Attitude subscale analyses.

Subscale	Control Gain	Additional Treatment Gain	p-value
Views Towards Math	-0.07	0.08	0.34
Confidence Towards Math	0.03	0.11	0.28
Math Self Concept	0.00	0.07	0.43
Strategies Towards Math	0.01	0.00	0.96

On three of the four subscales, the gain for the treatment was higher than the control – this was particularly noteworthy for the confidence towards mathematics subscale – the model suggests that, in this case, the additional gain for the treatment over the control is approximately 3.5 times the gain of the control (i.e., .11 / .03 = 3.67) - this is not statistically significant but of a noteworthy size to warrant attention and further exploration. In addition, it is noteworthy that for two other subscales (math self-concept and views towards math), the gains for the treatment are positive where the gain for the control is either zero or negative.

The analysis of subscales suggests that the impact of BrainQuake puzzles on student attitudes is promising, particularly for improving their confidence towards mathematics.

Because there appeared to be positive effects for the attitude measure overall, we explored impact on attitudes by item to further characterize the effect. Rather than looking at all items, which carries high risk of false positive findings due to multiple tests, we reduced the size of our analysis by examining differential gains between the treatment and control group on the top three items that showed the largest difference between the groups, regardless of whether they were larger for the control or treatment. The top three items with the largest differential gains are listed, below.

(Believe Math Best Subject) I have always believed that math is one of my best subjects

(Strategy Search) When I cannot understand something in mathematics, I always search for more information to clarify the problem.

(Confidence Solving) How confident do you feel about having to do the following calculation? Calculating how much cheaper a TX would be after a 30 percent discount?

Consistent with above effects, gains on all three of these items were positive, and in all cases, larger for the treatment relative to the control group. In other words, *items with the largest differences in relation to pre-to-post gains exclusively favored the treatment condition*. In addition, these items are in alignment with the BrainQuake logic model – for instance, by design, students can arrive at solutions to BrainQuake puzzles in a variety of different ways; thus, BrainQuake games are expected to support students' strategy search. Moreover, one of the puzzles (Tanks) targeted students' proportional reasoning, which is the subject of the question about confidence. Finally, because BrainQuake supports students' confidence towards mathematics, it is expected to positively increase their views towards mathematics.

To characterize the size of the observed gains on these top three items, we parsed students into having shown a positive gain or not (zero or negative gain), and conducted a generalized hierarchical linear model for each question, with condition as a predictor and controlling for the pre-test score, while also including a random effect for teacher. We then examined the odds ratio for the condition variable from these models.

Table 14. Odds ratio analyses.

Top 3 items with Largest Gains	Treatment Odds Ratio	p-value
Believe Math Best Subject	1.90	0.01
Strategy Search	1.89	0.007
Confidence Solving (proportion)	1.41	0.15

As can be seen from the Table 14, the treatment was approximately 1.5 - 2 times more likely to gain on these three questions relative to the control group. In two of the three cases, the difference in the gains are statistically significant. In all cases, these results are practically significant.

Student Persistence

Student persistence was seen in two ways: 1) accomplishing difficult puzzle levels 2) overcoming technical issues with BrainQuake app. Student persistence was reported organically when students patiently worked through difficult puzzles. During one observation, the researcher noted a student-teacher interaction, "I want you to struggle a little bit. I can't always give you the right answer." One 5th grade teacher described in detail how he established the norm of persistence from the beginning of the study.

> "[In the] first session, the students said I don't understand how to do it. I would give him a little hint and from there on, they worked on it on their own. After first session, the students were able to push through challenging puzzles. They discovered it wasn't as hard as they originally thought, if they sat and thought about it first. This is the typical format of my class."

Students discussed their determination to complete challenging puzzles, "When we didn't solve the questions right away, we were more determined to complete the puzzle and get it right."

Student persistence was also enforced through classroom implementation rules set by the teachers. Some teachers required students to complete each puzzle with three stars, so students were forced to replay puzzles. When students were not asked to replay levels to three stars, classroom observation data shows students selected the next button before counting the number of stars. During the focus groups, the vast majority of students reported only focusing on the diamonds and not the number of stars. One student mentioned, "The thing I like is that it at least gives you one star."

The vast majority of students reported struggling to solve puzzles is part of the video game experience, "Even when you play Call of Duty, yeah, it's the whole point of it. Because they want to challenge us to see how smart we are." When students were asked if they preferred a single pathway or multiple pathways to solve a problem, analysis of the qualitative data did not provide a clear preference. The majority of students from one classroom reported, "I like when there is only one way to solve the problem. Guessing is the only way I know. If it's easy, then I'll just do the work." In contrast, another group of students from a different classroom preferred the speed provided from multiple pathways, "I like it better because you can move onto a level faster. It takes you way longer when there is only one single way [to solve the problem]."

Student post-survey indicated, as shown in Figure 16, that if students didn't get the puzzle correct on the first try, (47%, 51%, and 53%, respectively) felt optimistic about trying to solve the puzzle again.

Figure 16: Student Post-Survey Respondents Indicated That If They Didn't Get the Puzzle Correct on the First Try, 47%- 53% Felt Optimistic About Trying to Solve the Puzzle Again

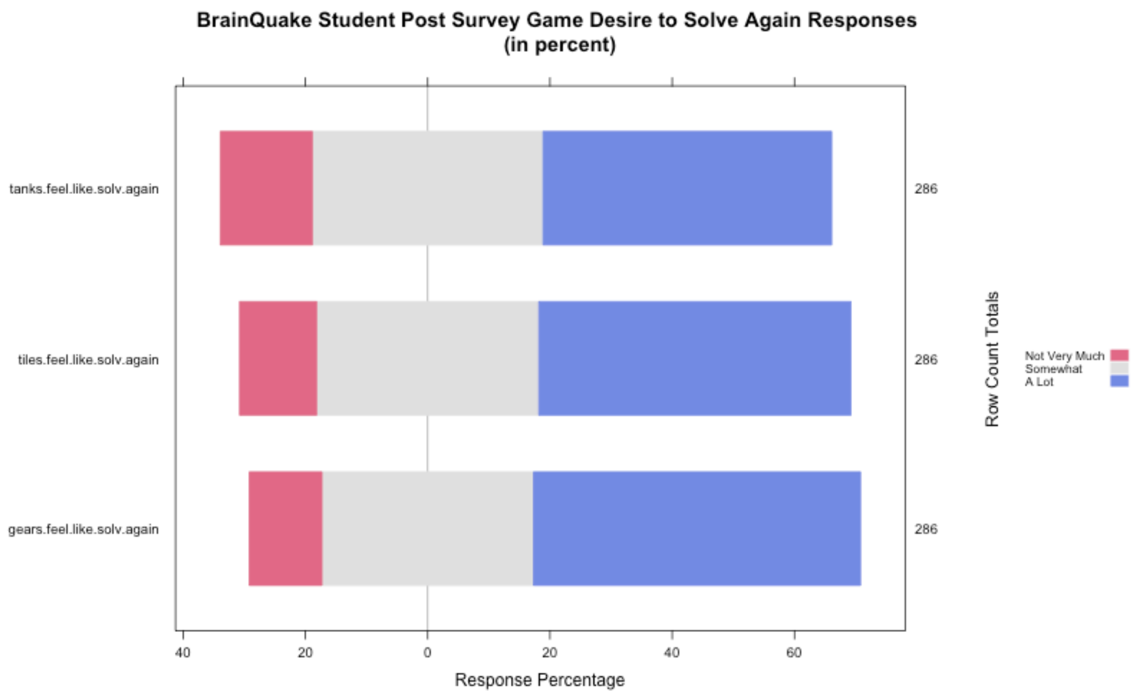
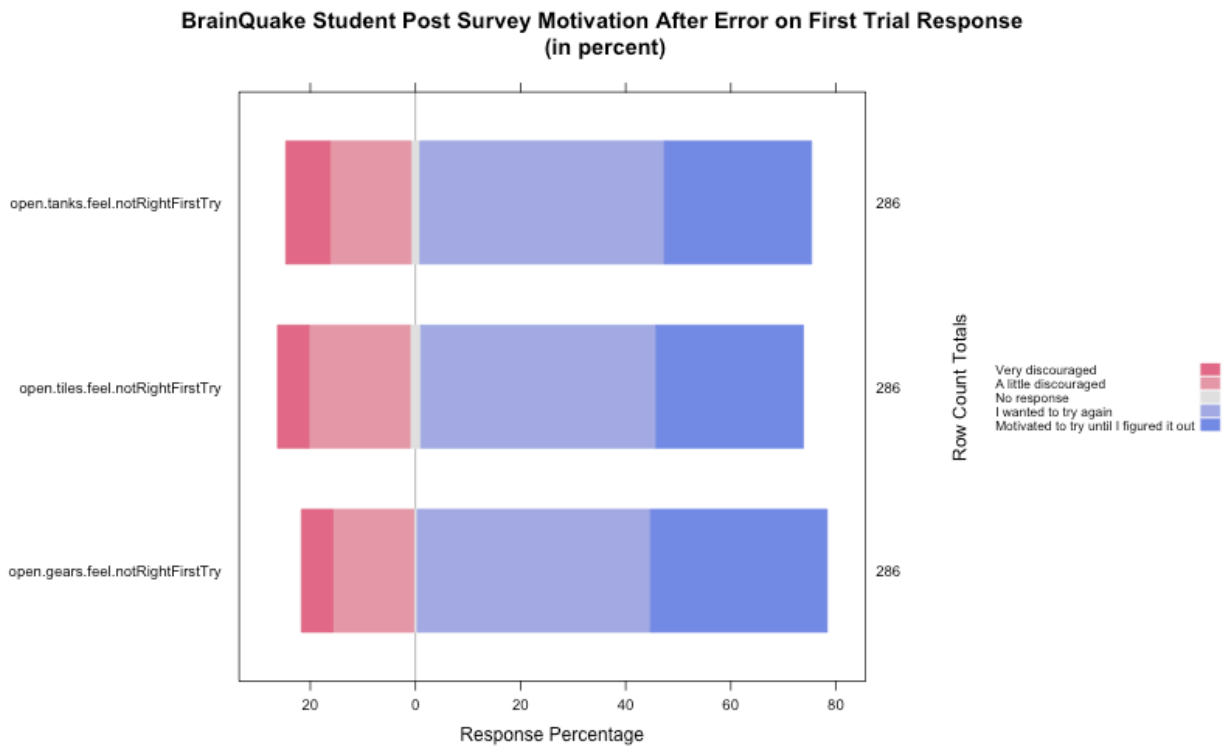


Figure 17 show student responses to the post-survey question, "If I didn't get one of the Tanks/Tiles/Gears puzzles right on the first try, I was motivated to think of new or different ways to get to the right answer". The Gears puzzle, by a slight margin, seemed to provide the most motivation to encourage the students to try again or try until the puzzle was figured out (74%, 73% and 78%, respectively).

Figure 17: Student Post-Survey Respondents Indicated That If They Didn't Get the Puzzle Correct on the First Try, 74%- 78% Felt Motivated to Think of New Ways to Get the Right Answer



RQ 3: What is the impact of the BrainQuake puzzle suite on teachers' pedagogical content knowledge for teaching?

Impact on Teachers Pedagogical Content Knowledge

Teachers were provided an opportunity to complete the Mathematical Knowledge for Teaching (MKT) questionnaire both at the beginning and end of the study, providing the opportunity for us to assess whether MKT changes over the course of the study. One reason why teachers might increase in their knowledge for teaching mathematics is because of the opportunities that BrainQuake puzzles provides for supporting students' problem solving. For example, in this and earlier work, we have observed teachers walk around the room and provide assistance to students – teacher assistance often involves back and forth dialogue aimed at supporting the student through the mathematical challenge. Thus, these scaffolding interactions may serve as opportunities for teachers to both gain insight about their students' understanding of mathematics, as well as provide practice at supporting students in mathematical problem solving.

The number of teachers that provided complete pre- and post- data for the MKT was low ($N_{control}$ = 7, $N_{treatment}$ = 9), thus, we view these analyses as exploratory. The impact of the BrainQuake puzzles on teacher MKT was examined via single-level regression model, regressing post-MKT score on the condition assignment variable, controlling for pre-MKT score, years of experience teaching, grade taught, and the proficiency of using technology for teaching (calculated from the background questionnaire at pre-study).

The main effect of condition in this model was not statistically significant, but was positive and of a notable size for educational impact – specifically, the effect of going from the control to the treatment condition on post-MKT score was 2.67 (SE = 2.10, p = 0.23). The effect size for this effect was 0.40, which is a substantial size for education and suggests the intervention holds promise for supporting teachers' mathematical knowledge for teaching.

Conclusions and Next Steps

The study showed largely positive findings and support the conclusion that BrainQuake's puzzle suite is a promising tool that can be used to support middle-school teaching and learning in mathematics. Teachers and students used the puzzles in a variety of ways, with minimal training, speaking to the puzzle suite's ability to be flexibly adapted by teachers in diverse contexts. The puzzles were also largely perceived positively by both teachers and students, even in spite of some technical issues experienced. One consistent finding across the pilot study (as well as prior usability/feasibility studies) is that the puzzle games are highly engaging for students – students displayed extraordinary persistence at trying to solve the puzzles, even after indicating that they had failed multiple times. The puzzles' ability to incite persistence even in the face of failure is a key benefit of the BrainQuake puzzles, and may have contributed to the consistently positive impacts we observed in students' attitudes towards mathematics. The potential for BrainQuake puzzles to increase student attitudes towards math is non-trivial, as it could potentially result in significant downstream benefits that could positively influence students' mathematics learning trajectories in the long-term.

Though we believe these results support BrainQuakes' puzzles suitability for classroom contexts, after reviewing results from the study, we believe that a few modifications to the puzzle suite will further enhance BrainQuake's value and impact. Below, we provide some points of discussion for modifying the games going forward. These discussion points are based on our understanding of teachers' and students' feedback, as well as our own observations—with the goal of further improving the product for classroom use.

Game Modifications

- **Further build out the digital manipulatives (DM) versions for each puzzle.** BrainQuake's innovative design platform allows students to engage in mathematics in a positive way – at the same time, students are assessed by tests that inevitably require traditional mathematical notation of formal schooling – DMs provide the link between these. We believe DMs will further improve the products' impact on students' achievement outcomes.

- **Consider making Tiles and Tanks adaptive to students' game performance.** Some students reported the Tiles and Tanks were extremely difficult, whereas students in the same class asked to make Tiles and Tanks more difficult and add a timed component to the completion of the puzzles.

- **Teachers and students requested adding embedded hints and feedback to scaffold the game** play experience for students who are struggling to complete certain puzzles. Because 5th graders had not covered ratios and proportionality in fall semester, one teacher recommended adding introductory videos to present new math concepts.

- **Teachers also asked for a tutorial video** to show students how to navigate the suite of games.

- **Students and teachers suggested several game enhancements** to improve student engagement:

    - Story line intro to the suite of BrainQuake games

    - Bonus level for completing ten puzzles

    - Holiday versions of Wuzzits

- Two player version

- **Students and teachers requested the games be used on a tablet and incorporate the touch feature.** Teachers and students specifically reported manipulating the gears on the trackpad "hurt their hands".

Classroom Implementation Modifications

- **Teachers suggested that having an explicit reference to state standards** would help provide both more context for the teachers and allow them to integrate the BrainQuake suite of games appropriately into their classroom.

- Teachers were adamant that the **timing of the implementation would be more appropriate if the students had access to the game when they were learning the associated material**. Based upon this feedback it was suggested that the BrainQuake suite would be most beneficial for students when it can align with their current curriculum.

- **Teachers requested that PDF versions of the BrainQuake training would be helpful to have throughout their use of the suite of games**. Providing teachers with screenshots from each of the games and associated instructions on how students can progress through these puzzles would be beneficial for the implementation of the suite of games.

- **Students and teachers expressed that the game may have been more accessible and easier to navigate through an iPad.** Many students and teachers reflected that physically manipulating the puzzles through the iPad would make for an enjoyable experience.

- It was a common theme expressed by teachers that **a teacher dashboard would be a valuable addition to the BrainQuake suite of games.** Teachers can use this as a tool to measure both gaps in the students' knowledge as well as a means to hold students accountable for the amount of time and puzzles they complete.

- Teachers furthermore identified that **having structured lessons as an introduction to the different games (Gears, Tiles, Tanks)** would be helpful for students as they progress through the suite of games.

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Appendix

This appendix contains the tables referred to in the body of this report.

Table 4. Student Mathematics Achievement Assessment

<table>
<tr><th>Item Theme</th><th>Item #</th><th>Item Statement</th></tr>
<tr><td>Number Sense</td><td>1</td><td>Which of these numbers is between 0.07 and 0.08?</td></tr>
<tr><td></td><td>3</td><td>In which list are the numbers ordered from greatest to least?</td></tr>
<tr><td></td><td>4</td><td>Which of the following is the decimal representation of 28 / 36 and correctly identifies whether the decimal is terminating or repeating?</td></tr>
<tr><td>Solving for an Unknown Quantity</td><td>2</td><td>During gym class, Jami jumped 4.5 feet. Brenda jumped 3.72 feet. How much farther did Jami jump than Brenda?</td></tr>
<tr><td></td><td>5</td><td>A painter had 25 L of paint. He used 2.5 L of paint every hour. He finished the job in 5.5 hours. How much paint did he have left?</td></tr>
<tr><td></td><td>6</td><td>Which of the following is 70% of 48?</td></tr>
<tr><td></td><td>7</td><td>David bought a baseball card for $40. Since then, the card has increased in value by 25%. What is the value of David’s card now?</td></tr>
<tr><td></td><td>8</td><td>Liam wants to buy a bicycle that costs $335.00. His parents say Liam must raise 20% of the money himself. How much money must Liam raise?</td></tr>
<tr><td></td><td>9</td><td>Thea made the table below to show the number of middle school students who attended the last football game. If this data were displayed in a circle graph, what percent of the graph would represent the eighth graders who attended the game?
<table>
<tr><th>Grade</th><th>Number of Student in Attendance</th></tr>
<tr><td>6</td><td>375</td></tr>
<tr><td>7</td><td>275</td></tr>
<tr><td>8</td><td>350</td></tr>
</table></td></tr>
<tr><td></td><td>10</td><td>If 50% of a number is 20, what is 75% of the number?</td></tr>
<tr><td></td><td>11</td><td>Four stores are having a sale on DVDs. Which store is offering the best deal?</td></tr>
<tr><td></td><td>12</td><td>When a new highway is built, the average time it takes a bus to travel from one town to another is reduced from 25 minutes to 20 minutes. What is the percent decrease in the time taken to travel between the two towns?</td></tr>
</table>

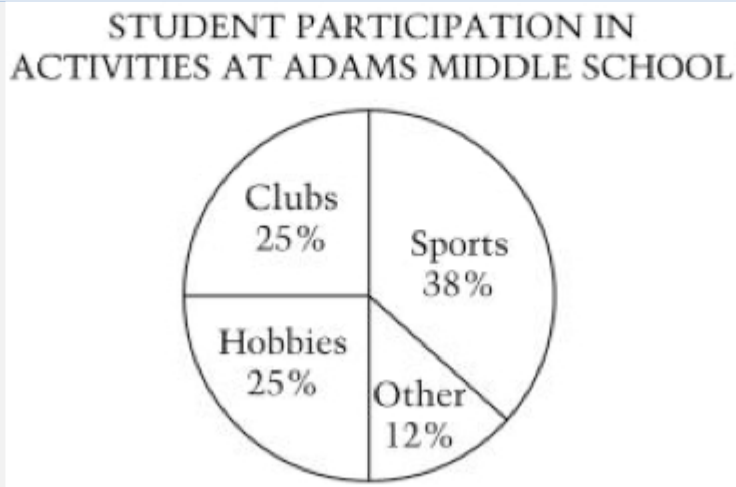
	13	 There are 900 students enrolled in Adams Middle School. According to the graph above, how many of these students participate in sports?
	14	Of the following, which is the closest approximation of a 15 percent tip on a restaurant check of $24.99?
	15	Kate bought a book for $14.95, a toy for $5.85, and a game for $9.70. If the sales tax on these items is 6 percent and all 3 items are taxable, what is the total amount she must pay for the 3 items, including tax?
	16	Ground beef costs $2.59 per pound. What is the cost of 0.93 pounds of ground beef?
Open-Ended Questions	17a	Lee works 22.5 hours each week and earns $9.48 per hour. What amount of money does Lee earn each week? Show or explain how you got your answer.
	17b	Each week, $25.60 is taken out of Lee's earnings for taxes. What percent of Lee's weekly earnings is taken out for taxes? Show or explain how you got your answer.
	17c	Lee wants to buy a car that costs $3,000. Lee plans to save all earnings that remain after taxes are taken out. What is the minimum number of hours that Lee must work in order to save $3,000 to buy the car? Show or explain how you got your answer.
	18a	For each of the following problems, estimate the product using benchmark values AND describe your reasoning. 2.4 X 0.8 = ?
	18b	5.21 X 0.4 = ?

Table 5. Student Attitude Survey

Item Theme	Item #	Item Statement
Personal Identification	1	Name
	2	Teacher's Name

	3	BrainQuake ID
Views on Mathematics	4a	I enjoy reading about mathematics.
	4b	Making an effort in mathematics is worth it because it will help me in the work I want to do later on.
	4c	I look forward to my mathematics lessons.
	4d	I do mathematics because I enjoy it.
	4e	Learning mathematics is worthwhile for me because it will improve my career prospects.
	4f	I am interested in the things I learn in mathematics.
	4g	Mathematics is an important subject for me because I need it for what I want to study later on.
	4h	I will learn many things in mathematics that will help me get a job.
Confidence in Mathematics Calculations	5a	Using a train schedule, how long it would take to get from City A to City B.
	5b	Calculating how much cheaper a TV would be after a 30 percent discount.
	5c	Calculating how many square feet of tiles you need to cover a floor.
	5d	Understanding graphs presented in newspapers.
	5e	Solving an equation like 3x +5 = 17.
	5f	Finding the actual distance between two places on a map with a 1:10,000 scale.
	5g	Solving an equation like 2(x+3) = (x+3)(x-3)
	5h	Calculating the fuel efficiency – miles per gallon of gas (mpg) - of a car.
Math Self-Concept	6a	I often worry that it will be difficult for me in mathematics classes.
	6b	I am just not good at mathematics.
	6c	I get very tense when I have to do mathematics homework.
	6d	I get good grades in mathematics.
	6e	I get very nervous doing mathematics problems.
	6f	I learn mathematics quickly.
	6g	I have always believed that mathematics is one of my best subjects.
	6h	I feel helpless when doing a mathematics problem.
	6i	In my mathematics class, I understand even the most difficult work.
	6j	I worry that I will get poor grades in mathematics.
Strategies Towards Mathematics	7a	When I study for a mathematics test, I try to work out what are the most important parts to learn.
	7b	When I am solving mathematics problems, I often think of new ways to get the answer.
	7c	When I study mathematics, I make myself check to see if I remember the work I have already done.
	7d	When I study mathematics, I try to figure out which concepts I still have

		not understood properly.
	7e	I think how the mathematics I have learned can be used in everyday life.
	7f	I go over some problems in mathematics so often that I feel as if I could solve them in my sleep.
	7g	When I study for mathematics, I memorize as much as I can.
	7h	I try to understand new concepts in mathematics by relating them to things I already know.
	7i	In order to remember the method for solving a mathematics problem, I go through examples again and again.
	7j	When I cannot understand something in mathematics, I always search for more information to clarify the problem.
	7k	When I am solving a mathematics problem, I often think about how the solution might be applied to other interesting questions.
	7l	When I study mathematics, I start by working out exactly what I need to learn.
	7m	To learn mathematics, I try to remember every step in a procedure.
	7n	When learning mathematics, I try to relate the work to things I have learned in other subjects.

Table 6. Student BrainQuake Post Survey

Item Theme	Item #	Item Statement
Personal Identification	1	First Name
	2	Last Name
	3	BrainQuake ID
	4	Teacher
	5	School
Engagement	6	I like doing BrainQuake puzzles
	7	BrainQuake puzzles were fun
	8	Other students my age would like BrainQuake puzzles
	9	I got bored doing BrainQuake puzzles
	10	I felt engaged when I played the BrainQuake puzzles
Usability / Feasibility	11	When I used BrainQuake puzzles, I knew what to do without anyone telling me.
	12	I think most kids would learn how to use BrainQuake puzzles very quickly.
	13	Playing BRAINQUAKE puzzles was confusing.
	14	The BRAINQUAKE puzzles should provide more hints or directions.
	15	BrainQuake puzzles fit well with our classroom activities.
Improved	16	I feel like I learned about math from using BrainQuake puzzles.

Learning and Motivation		
	17	I would use BrainQuake puzzles again to learn more about math.
	18	After using BrainQuake puzzles, I feel like I'm better at problem solving.
	19	After using BRAINQUAKE puzzles, I feel like I'm better at fractions and decimals.
	20	The BRAINQUAKE puzzles helped me understand how math works.
	21	The BrainQuake puzzles tutorials/directions were helpful.
Overall Game Perception	22	The BrainQuake puzzles were...
Individual Puzzle (Tanks, Tiles, Gears) Persistence Resilience	23, 28, 34	When I didn't understand one of the Tanks/Tiles/Gears puzzles, I would keep attempting it until I got it right.
	24, 29, 35	If I didn't get one of the Tanks/Tiles/Gears puzzles right on the first try, I was motivated to think of new or different ways to get to the right answer.
	25, 30, 36	The Tanks/Tiles/Gears puzzle has taught me that even if I fail at first, there are chances to improve and learn.
Motivation to Try Again	26, 32, 38	On the Tanks/Tiles/Gears puzzle, if you didn't get the puzzle right on the first try, how much did you feel like trying to solve it again?
	31, 37	Playing the Tiles/Gears puzzle has taught me that even when I face challenging math problems, I can keep trying until I get it right.
Encouragement	27, 33, 39	If you didn't get the Tanks/Tiles/Gears puzzle right on the first try, how did it make you feel?

Table 7. Teacher BrainQuake Post Survey

Item Theme	Item #	Item Statement
Personal Identification	1	First Name
	2	Last Name
	3	School
	4	District
Student Engagement	5a	My students enjoyed using BrainQuake puzzles.
	5b	My students had fun using BrainQuake puzzles.
	5c	My students wanted to play BrainQuake puzzles even without me telling them to.
	5d	My students got bored playing BrainQuake puzzles

	5e	My students were engaged when they played the BrainQuake puzzles
Usability / Feasibility	6a	I thought by students found BrainQuake puzzles easy to use.
	6b	Using BRAINQUAKE puzzles in the classroom is helpful for my students.
	6c	Using BRAINQUAKE puzzles in the classroom was easy to do.
	6d	Using BRAINQUAKE puzzles was confusing for my students.
	6e	BrainQuake puzzles fit well with our classroom activities.
Improved Learning	7a	I feel my students learned about math from using BrainQuake puzzles.
	7b	I would use BrainQuake puzzles again to teach my students more about math.
	7c	After using BrainQuake puzzles, I feel my students are better at problem solving.
	7d	After using BRAINQUAKE puzzles, I feel my students are better at proportional reasoning.
	7e	The BRAINQUAKE puzzles helped me understand how math works.
	7f	The BrainQuake puzzles tutorials/directions were helpful for my students.
Overall Game Perception	8	For the students in my classroom, the BrainQuake puzzles were...
Teacher Engagement	9	What did you like about using the BRAINQUAKE puzzles in your classroom?
Technical Challenges	10	Were there any obstacles associated with using BRAINQUAKE games in your classroom?
Student Difficulty	11	Were the BRAINQUAKE puzzles at the right level of difficulty for your students? Why or why not?
Future Classroom Usage	12	How would you use the BRAINQUAKE puzzles in your classroom if you were to do this study all over again?
	13	Would you recommend BRAINQUAKE puzzles to other colleagues? Why or why not?
Individual Puzzle Comparison (Tanks, Tiles) Enjoyment Engagement Challenge	14	Did you observe differences in students' experience (e.g., enjoyment, engagement, challenge, etc.) when playing the Tiles games compared to the Tanks games? Or were students' experiences similar for the Tiles and Tanks games?
	15	Is there anything else you would like to share about your experience?

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