Improving MathSpring with Minigame Breaks and Translation

A Major Qualifying Project

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Abstract

The goal of this project was to make MathSpring, the math tutoring software, more accessible to Latinx students. As a result of my research and the process of improving MathSpring, two distinct paths emerged. The first of these goals remained in line with the original purpose, improving MathSpring's usability for Latinx, specifically Spanish-speaking ELL Latinx, students by translating the content from English to Spanish. The second goal was broader - improving all students' experience with MathSpring through intrinsically motivating mini-game breaks. To see if the mini-game breaks were effective in improving student affect while using MathSpring, I organized a study with two classes of middle school students. Half of each class had a random chance of receiving break prompts, while the other half were control and did not receive breaks prompts. All students self-reported on frustration during the study, and answered a brief survey afterwards. Students who received break prompts reported high levels of frustration less frequently than those without, and many students expressed interest in having game breaks in the survey.

Acknowledgements

First and foremost I'd like to thank my two advisors, Professor Ivon Arroyo and Professor Alexandrina Agloro, for their invaluable advice and guidance during this project. As a one-woman team I relied on their input on the direction of the project so the view wasn't so narrow. They always pushed me to improve the project and myself as much as possible, and taught me to laugh in the face of imposter syndrome. I'd like to extend my gratitude to the Worcester Polytechnic Institute George C. Gordon Library and Interactive Media and Games program, whose resources I made use of not only during this project, but through my entire undergraduate career. Finally, I am grateful for my friends and family who supported me this year, and without whom this project wouldn't have gotten past background research.

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1 Introduction

In the modern era of ubiquitous computing, educators are seeing the incredible motivational power of games. The idea that educators could harness this motivational power has fueled the growth of the 'edutainment' industry. Games as learning tools are powerful motivators for students who are otherwise disenfranchised by school. Marginalized students, including students of color, students with learning disabilities, female students and students for whom English is a second language, are sometimes not well served by traditional schooling. By reaching out to those students who are often left behind, educational games can be an important step forward. If games are the ultimate in intrinsic motivation, students who are marginalized are the ones who need games as part of their learning experience the most. I believe that if educational games only cater to those who are already performing well in school, then those games are failing to push for positive progress.

Many options exist in the world of games and interactive media for education This research examines MathSpring, an interactive, intelligent math tutoring system created originally as a part of a larger educational game called Wayang Outpost. Wayang Outpost was created by researchers at University of Massachusetts at Amherst to study the effect of an intelligent tutor in the form of a computer game on math learning in students. Specifically, the research looked at strategic behavior and math fluency. Strategic behavior in math education is defined as how a student would solve a difficult or higher-level math problem, and math fluency is the speed with which a student can answer basic math equations or calculations (Arroyo, Royer and Wolf, 2011). This project started with a broad question: How can we improve MathSpring for Latinx students? Research, exploration, and the resources available shaped the project into what it is today.

The first step of the research process was to review prior research done in relation to MathSpring. In doing so, certain needs were brought to light (see Section 2.4 for this review of prior research). Low achieving math students often have trouble engaging with mathematics material, no matter how it is presented. MathSpring was no different for these students, but that could be changed. One study on the affect of students using MathSpring showed that having breaks where students were able to play a math skills mini game improved their attitude towards MathSpring (Rai, 2016).

Research with MathSpring also brought up concerns about the accessibility of the software to Latinx students. This concern was backed by research on how English Language Learning (ELL) students perform on math word problems (see Section 2.2). Since many Latinx students are Spanish-speaking ELL students as well, improving the usability of MathSpring for Spanish-speaking ELL students would address this concern.

Research shows students who lack motivation to engage with math learning perform poorly, and students who can not understand math word problems perform poorly (Reinhard Pekrun, 2005; Fry, 2007). These two problems became the two branches of this project. In one branch I continue Dovan Rai's research into how breaks affect students in relation to MathSpring. In the other branch I provide translation for Spanish-speaking students. For the purposes of this paper, I will be using the phrase Latinx students to refer to Spanish-speaking ELL students of Latin American descent of all genders. Adding game breaks serves to improve students' affect, and translating the math problems makes MathSpring more accessible to Latinx students. The ultimate goal of this work is to make MathSpring enjoyable and accessible for all students.

2 Background

I found and analyzed various sources of evidence to gain a deeper understanding of the multiple problems at hand, and how MathSpring may be improved. An understanding of current math education practices and how those practices affect ELL students, and specifically Spanish-speaking ELL students, is important to move forward to better practices for those students. Looking at the history of educational games and how they have succeeded or failed leads to a better understanding of how to move educational games forward as a medium.

The following section will outline each of these in further detail.

2.1 Math and Emotions

One theory of student emotions in educational psychology is the 'control-value' theory, which posits that a student's emotions towards an academic task depends on how much control they believe they have in the task and how much they value the topic (Pekrun, 2006). When brought into the math classroom, this theory can help educators to better scaffold their students with what kinds of academic achievements they offer, the type of educational environment they provide, and more (Pekrun, 2006). In surveys provided to math students based on the control-value theory, it was proven that the students' emotional response to math classes directly correlated with their academic success in mathematics (Reinhard Pekrun, 2005). These surveys also showed that girls reported significantly less enjoyment and pride, and significantly more shame and anxiety than boys (Reinhard Pekrun, 2005).

Society's pressures on students changes their value of mathematics, but not their actual skills. A study by Castambis (1994) showed that gender differences specifically emerge in the middle school grades. Female students begin to view their own skill in math as lesser than that of their male

counterparts, regardless of either group's actual skill level. This gap continues into adulthood, leading to a gender gap in math-related job fields (Castambis, 1994).

What begins affecting math skills is the emotions that come up when students are forced to work on something where they view themselves as inadequate. Two emotions that are common in learning environments that often get conflated with one another are confusion and frustration (Liu, Pataranutaporn, Ocumpaugh, Baker, 2013). Confusion is a lack of understanding, which is normal and means a student is pushing into new territory to learn. Frustration is not moving forward in a problem, and can be something known as "pleasurable frustration" which is similar to the feeling one gets when doing a difficult puzzle. Both of these emotions, if resolved in the right time frame, are conducive to learning. However, if the student feels frustrated or confused for too long, and does not resolve the problem, they begin to shut down. A student will feel inadequate and will not want to continue working on a subject if they are confused or frustrated without resolution (Liu et. al., 2013).

2.2 Spanish Speaking ELL Students and Math Education

With the recent trend in math word problems, language comprehensions skills are becoming crucial in math education. Common Core standards emphasize the importance of what they call 'real-life' problems, which are word problems (Common Core, 2017). Studies have shown that students perform significantly worse on math word problems that are inconsistently or confusingly written (Boonen, de Koning, Jolles & Van Der Schoot, 2016). If a student struggles to understand a problem, they will struggle to solve it. This is exacerbated in time-constrained conditions, such as standardized tests.

While this is a compelling argument for better reading comprehension education for all students, it also presents a problem unique to English Language Learning (ELL) students in math classes. If native English speakers are having comprehension difficulties with math word problems, non-native speakers must be struggling so much that their scores in mathematics suffer. This is indeed the case. National Assessment of Educational Progress standardized testing in 2005 showed that 46% of ELL students in the 4th grade performed "below basic" in mathematics - the lowest category possible. The same tests showed that 71% of ELL students in the 8th grade performed "below basic" in mathematics (Fry, 2007). It is not hard to observe that the language barrier is an obstacle to success on math assessments. Any assessment presented in English becomes an assessment of English proficiency (Martiniello, 2008).

These points open discussion of what can be done to change math assessments so that they are a more accurate measure of ELL students' math skills. One solution is to simplify the language used in math word problems. Abedi and Lord organized a series of studies and found that doing this can improve scores on math word problems for all students, and that the improvement is greater for ELL students as well as students with poorer reading comprehension skills (Abedi and Lord, 2001; Boonen et al., 2016). Beyond just simplifying language, studies have shown that providing a glossary of potentially unfamiliar terms as well as providing extra time for the exam allows ELL students to improve their scores fairly significantly. However providing only the glossary, without the extra time, showed no significant improvement (Abedi, Lord, Hofstetter & Baker, 2000).

Altering language, increasing time, and providing further explanation are all accommodations that are simple to make for exams. In the setting of an online interactive tutor, however, there are so many math problems that editing them in this way would be difficult. On most websites, a

rudimentary translation service is offered by the browser. This translation is often inaccurate, especially in matters of grammar. If the website provides the translation it can be more accurate. If the students are able to see word problems in both their native language as well as in English, it could help them to understand and answer the problem, as well as improve their English reading comprehension skills (see Section 3.1).

2.3 Educational Games

The 1980s gaming industry boom is seen as responsible for the launch of what is now known as the 'edutainment' (a portmanteau of 'education' and 'entertainment') industry. Educators craved the engagement from students that video games seemed to elicit, and so they tried to fuse education and video games into one thing: the educational game. Unfortunately, years of miscommunication between game developers and educators has left the word 'edutainment' tainted by scores of things that are both poor games and poor education. The whole reason for merging the two media was lost. The motivation that drives game players to keep going, to play their games again and again, and the motivation that drives the curious towards learning are one and the same: intrinsic motivation. The person experiencing the motivation is also the one creating it. If educational games could harness this intrinsic motivation, both good games and good educational content could come from them (Habgood and Ainsworth, 2011).

2.4 MathSpring

MathSpring was developed as a way to adapt problem sets on the fly so that students remained within what is known as the zone of proximal development. The zone of proximal development is the range of engagement and difficulty that is most conducive to learning. If problems are too hard, a student is confused and leaves the zone, as they are too frustrated to learn

anything. Similarly, if problems are too easy, a student is bored and does not have to be engaged to complete the problems, and therefore does not learn anything (Arroyo, Woolf, Burelson, Muldner, Rai & Tai, 2014).

Research with this math software did not stop there, it has also been used to examine how students interact with characters in a learning environment. A study by the MathSpring team examined the way students reacted to messages of encouragement, hints, and empathetic messages of frustration delivered by characters in Wayang Outpost (Arroyo, Schultz, Wixon, Muldner, Burleson and Woolf, 2016). The study also examined how that reaction differs between female students and male students, and whether or not the gender of the character altered the interaction. The results of the study indicated that female students were more sensitive to the learning companion character, having a positive reaction to any companion character, and a greater positive reaction to a female companion character. Conversely, male students preferred to not have a learning companion character at all (Arroyo, Burleson, Tai, Muldner, Woolf 2013).

The researchers found that student scores on standardized tests improved through use of the Wayang Outpost. This effect was enhanced with the use of the tutoring system as well as a math facts retrieval software that improved math fluency. The adaptive system designed to keep students in the zone of proximal development was effective in actually increasing student learning. Use of metacognitive support, through the animated companion characters, was important in students' feelings towards the software. The companion characters seemed to improve affect more in female and minority students than others. With improved affect towards the software, students are more open to learning with it, more engaged with it, as well as more willing to use it again (Arroyo et. al., 2014).

A series of studies were done in relation to MathSpring to examine the effect of math games on students. One study that directly involved the tutoring software was the creation of a mini game called Mosaic. This mini game was interspersed randomly within tutoring sessions with MathSpring. The game itself was math problems with a game-like element to it, played on the computer. Unfortunately, there were insufficient resources to perform a full study on these Mosaic breaks and their effect on students' frustration levels and affect. The study that was run showed that students tended to like the tutoring sessions more with these game breaks interspersed (Rai, 2016).

2.5 Recess and Breaks

The Mosaic experiment, where a math game was inserted into MathSpring as a break students could take, showed some improved affect and engagement from students (Rai, 2016). In the case of learning on computers it is important to examine the effects of breaks, especially those that get a student away from the computer briefly, on their learning. Most research has been done on the effect of traditional recess on students, or of breaks from working at computers for adults.

When groups of students are able to have recess of at least 15 minutes every day, their classroom behavior improves (Barros, Silver, & Stein, 2009). Unfortunately, since the introduction of No Child Left Behind to public schools, recess times have been cut down across the board. A study in 2007 showed that 20% of school districts had shortened recess by an average of 50 minutes each week to allow more instructional time for reading and math (McMurrer, 2007). These cuts are felt heavily in lower-income, less-white communities (Barros et. al., 2009). Even the minimum amount of recess has a positive impact on students' health, social skills, behavior, and academic achievement (Jarett, 2002).

In the world of software engineering, programmers work for hours at computers. This can cause problems physiologically if the programmers do not take breaks from sitting. Endless work can also negatively affect their productivity. Most experiments have focused on alleviating the physical damage, as productivity is a difficult thing to measure. A software was created to remind workers to take breaks and stretch or do other helpful exercises. The people who used this software reported less discomfort after an 8-week period (van de Heuvel, 2003).

3 Methodology

The problem presented to be solved at the beginning of this project was a big one - how to make MathSpring as a software more accessible, enjoyable, and helpful to Latinx students. I narrowed the scope to improving the software for specifically Spanish-speaking Latinx students. Prior research involving the learning companion characters indicated that female and students of color had improved attitude towards the program with appropriate characters. Overwhelming background research revealed that Latinx ELL students struggle in math classes due to the language barrier that they face. Thus, two avenues to improve the software appropriately were opened. Because the significance of the language barrier outweighed the significance of the companion characters, I decided to translate the word problems, and any further changes I would make to the software, to Spanish. This translation was done under the guidance of Professor Ángel Rivera, Spanish professor at Worcester Polytechnic Institute.

In researching what was to be done to address MathSpring in regards to Latinx students, another avenue of interesting thought on how to improve the software for all students came up. The addition of break activities could improve student affect towards MathSpring. Dovan Rai's research with MathSpring already began to explore this possibility, but I found a few things I wanted to

change about that research. The game used in Rai's mini-game breaks used extrinsic motivation to get students to be interested in math. I wanted to use intrinsically motivating math activities to give the students a break from the feeling of a problem worksheet. My first thought was to design new games to teach students math using intrinsic motivation. This design experiment led to two basic design documents (Appendices 1 and 2).

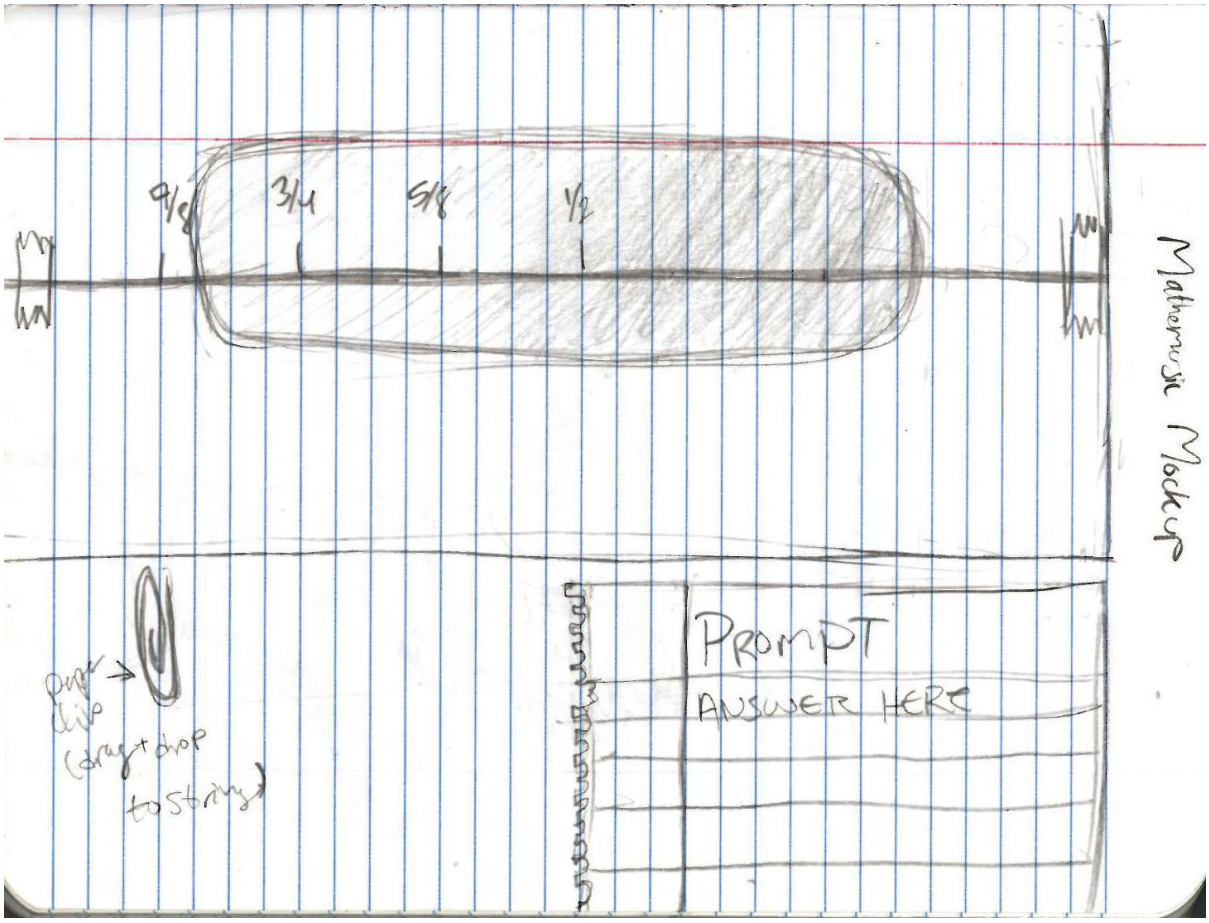

Figure 3.1: Mathemusic UI Mockup

Mathemusic, one of the games, was based on the relationship between math, physics, and music. As someone who has played guitar for most of her life, it made sense to me to cover basic fraction-sense with a simulated guitar. Musical notes are a base-eight fraction system, and beats can be another way to explore fractions. The way a string instrument makes different notes is also by

effectively dividing the string into fractions of itself and striking it. Using GameMaker Studio I was able to create a bare-bones tech demo of Mathemusic, seen below.

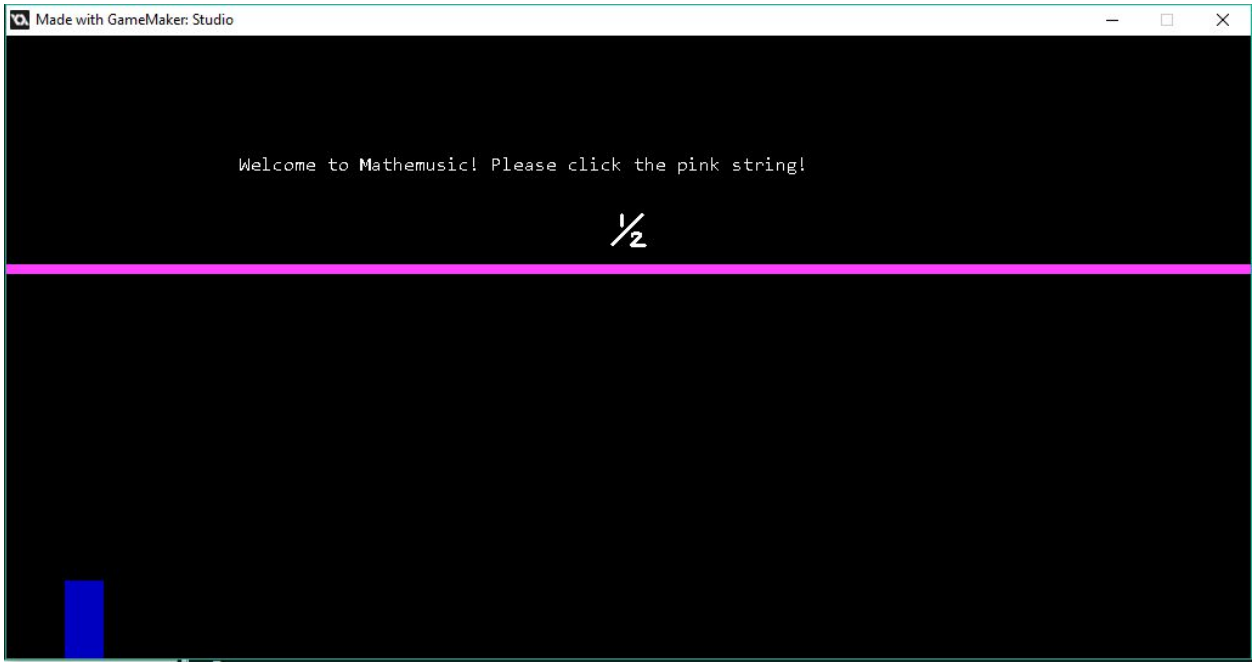

Figure 3.2: Mathemusic Demo

Due to time and resource restraints, creating Mathemusic or any of the other games explored was out of scope. Instead, I set about finding intrinsically motivating games that already existed that could be used as breaks. I found four different games, each related to four different math topics - geometry, fractions, algebra, and number sense. I then broke MathSpring's problem sets into those four topics so that a student could do a break activity that was related to what they were studying in MathSpring.

The geometry activity chosen was a classic math puzzle - tangrams. These puzzles allow students to think critically about shape, size, and orientation of geometric figures. A more specific activity for perimeter and area was needed, so I found Party Designer, a game in which the player makes rectangles of a certain area and perimeter within a constrained space. This requires knowledge

of rectangular area and perimeter, but also planning skills. If a player makes their rectangles in such a way that all of them can't fit, they need to start over. For fractions, a Pearson Education game called Hamster Hotel was chosen. Players use an elevator to send the appropriate number of hamsters to fill up a floor. They are manipulating numbers and thinking about fractions of how full the floors are. Algebra was represented by logic puzzles. These puzzles are randomly generated and are solved by filling in a table of which statements are true and which are false. Logic puzzles are less related to math but have everything to do with solving algebra problems - thinking about missing information. Expressions and order of operations are explored in Calculator Chaos. Players are attempting to create certain numbers on a broken calculator that is missing a number of buttons, including numerals and functions. This is a new way to look at solving math problems for most students. To explore negative numbers a game called Piñata Fever was selected. In this fast-paced game players move around a number line by creating certain numbers through adding or subtracting both positive and negative numbers. Finally, number sense is explored through a Brainpop game called Battleship Number Line. In this game students estimate where on a number line to fire missiles, like in the classic board game Battleship. This allows them to get a new visual representation of numbers on a number line.

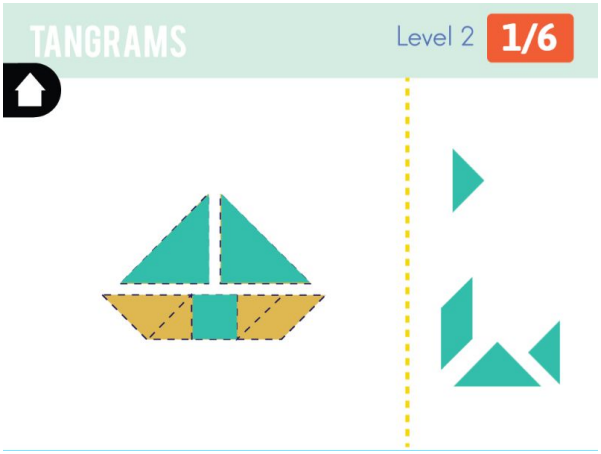

Figure 3.3: Tangrams Activity (ABCya, 2017)

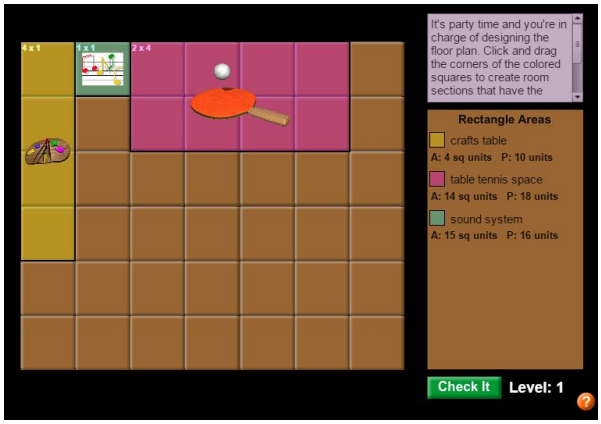

Figure 3.4: Perimeter Activity (Party Designer, Mathplayground, 2017)

Figure 3.5: Fractions Activity (Hamster Hotel, Pearson Education Inc., 2017)

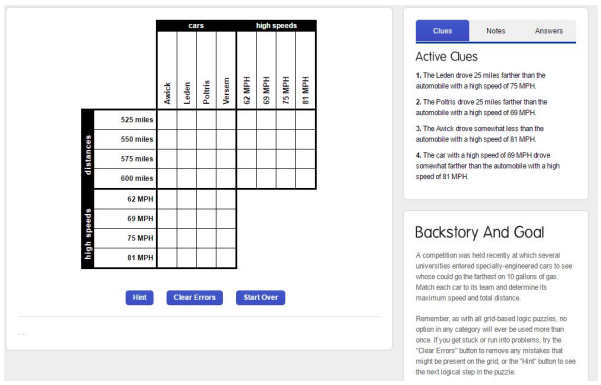

Figure 3.6: Algebra Activity (Logic Puzzles, Puzzle Baron, 2017)

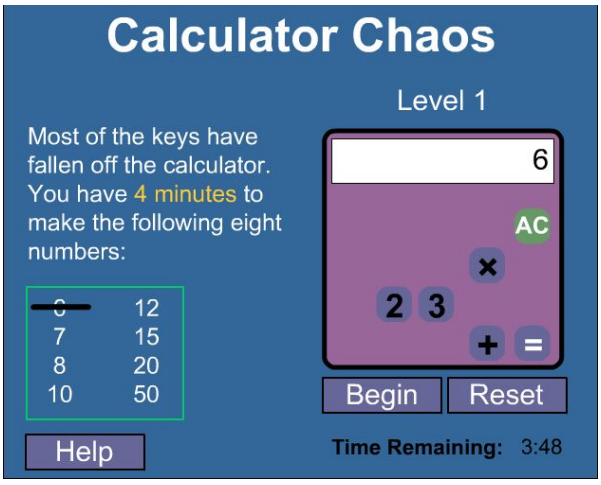

Figure 3.7: Expressions & Order of Operations Activity (Calculator Chaos, Mathplayground, 2017)

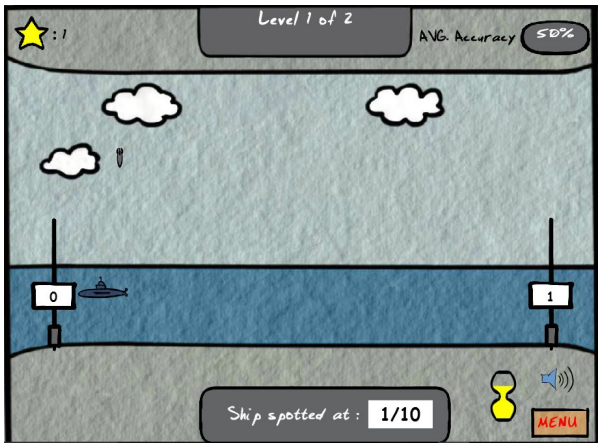

Figure 3.8: Number Sense Activity (Battleship Numberline, BrainPOP, 2017)

Figure 3.9: Negative Numbers Activity (Piñata Fever, Mangahigh, 2017)

To round out the background research, two studies were performed before the changes were implemented into MathSpring. The first was a semi-structured interview with David Yale, the second a survey of prior data gathered in experiments with MathSpring. To examine how the changes affected student experience, three studies were proposed to answer three separate questions: do the mini-game breaks help students? Should the breaks be timed or emotionally triggered? And finally, is there a difference between having digital break activities versus physical ones? These studies would collect data through pre and post surveys of students, and MathSpring's built in affect-monitoring. Only the first of these studies was performed, answering whether or not mini-game breaks help students. The other two proposed studies can be found in Appendices 4 and 5. The surveys and studies were based on Dovan Rai's study of how Mosaic breaks affected student experience. The questions for the surveys were based upon the surveys from those studies, but were edited as well as translated to Spanish. These questions were used because I thought they accurately pursued the same information from the students that I pursued.

3.1 Study 1: Interview with David Yale

The interview with David Yale was held September 16th, 2016. It was a semi-structured interview conducted over Google Hangouts with just audio, rather than audio and video. David's responses were audio recorded during the interview, and later transcribed. Yale is a Ph.D. student at UC Santa Barbara who has conducted studies with MathSpring in the past, and has other experience in math education. I spoke with him to get an idea of how an educator who has conducted experiments with MathSpring feels that the software could be improved. For a full transcript of Yale's responses, see Appendix 3.

3.2 Study 2: Prior Survey Data

In surveys of students delivered after doing exercises with MathSpring, there were 167 responses collected over the course of four separate testing sessions. These surveys were delivered through an online survey after students completed MathSpring tests with different conditions in different locations. The questions observed were ones that asked students for suggestions for improving MathSpring. I categorized the responses based on what the student's suggestion had to do with. After doing so, I analyzed the results to determine if the students wanted the kinds of changes this project would bring.

3.3 Study 3: Observing Affect in Response to Break Activities

To examine the effect of the break activities on the affect of students using MathSpring, a study was performed. This study was run in two classrooms, one 7th grade and one 8th, and used the system that is already in place to observe student affect while using MathSpring. Students used MathSpring as normal, and between problems there was a 10% chance that they received an option to do a math activity. These activities are the digital math activities described in Section 3, and were

attached to a problem set related to the topic covered in the activity. Student affect was recorded as normal in the MathSpring software. Student frustration was measured through the in-tutor questions. Students also received a survey at the end of the study to get qualitative data on their experiences with MathSpring. See Appendix 6 for the full list of survey questions. There was a control group of students who did not receive break activity prompts. The students who received the activity prompts and those who did not were randomly selected, 50% of the students received prompts and 50% did not.

The expected outcomes were that the frustration levels reported by students after the break activity prompt would be lower than their frustration levels reported before the break activity. So the students who received the prompts should have reported lower frustration overall. See results in Section 4.3.

4 Results

The first two studies discussed provided important guidance in how best to improve MathSpring. Those sections analyze the data collected from the sources about MathSpring and explain how that information shaped the decisions and the project moving forward. The final study discussed examined the effect of the project on student affect.

4.1 Results of Study 1

Speaking with Yale revealed information not only about MathSpring and his experience with it, but also his experience in teaching. These qualifications make him an appropriate person to judge MathSpring as a teaching tool. He reported experience teaching low level math courses as well as high level tutoring. He described the students' emotions in his low level courses as having a sort of sadness, having been beaten down by math failure and being unwilling to try again. Much of his

work teaching these students was in getting them engaged with the material. Often, if a student is learning math that is considered lower level than their grade level, the teaching materials related to that math concept will be thematically for a younger audience. Yale worked to engage the students by making the math exciting for them, specifically, often theming word problems around an interest of the student.

In his work conducting MathSpring studies, Yale observed some trends among students having difficulty engaging with the software. Generally the students would do anything they could to avoid engaging with the software, clicking randomly rather than paying attention to it. With those students it is often hard to tell why they are disengaged, especially in shorter studies where it could just be the mood of that day. With ELL students in particular, Yale found that those students had difficulty even understanding instructions given by the teachers. Those students were usually helped by a neighbor, which Yale encouraged. When they were not helped, the students would often wait until they were very far behind, but the class had settled down, and then ask for help. Yale believed that it was as if they did not want to rock the boat or stick out for needing help. When he could, Yale would attempt to empathize with the student by communicating in Spanish, which he described as "the worst possible broken Spanish I can muster," which would allow them to perceive him as vulnerable. He let them reach out and feel safe asking for help because he showed himself as imperfect, and that those students belonged.

Having worked with the software, Yale had some ideas for improvements. He said that having a Spanish or 'Spanglish' version of MathSpring for Spanish-speaking ELL students would be a minimum for their success. He also explained a system of choice for the students to have a themed experience. Much like the way he themed his teaching around a student's interest, he would like to

see MathSpring offer themes for students to choose from so they feel more in control and interested. He also suggested an improvement to the feedback the software provides, both to teachers and to students. He described a system where the students could receive some more feedback that could help them think about their own learning from a self-reflection, self-evaluation perspective. For teachers, the changes were partially in interface- making the data they receive easier to parse- but also giving them access to assign certain problems for students, like homework. He'd also like the teachers to have access to the distribution of students with certain levels of progress, and then have them be able to see which students exactly lack in progress so they are able to provide remedial care. Overall, his suggestions were to make the software easier to understand for everyone, and more motivating for students to learn as much as they can.

Many of Yale's suggestions were taken into account with the design of this project, but some of them had to be left for future work. His idea that the best way to help Spanish-speaking ELL students would be to provide a translation and a side-by-side with the English version of the problems was exactly what was done in the translation portion of the project. He also brought up many points on student motivation that were explored through this project, as well as through research. Much of what was said about the design and interface was passed on to a separate team working on improving the way MathSpring looks. His goal of making it more accessible for students was the same as the project's goal.

4.2 Results of Study 2

Of the 167 responses analyzed, 26 responses had to do with games specifically. This is almost 15% of the responses, the other highest percentages being 41% non-constructive feedback, and 18% issues with the difficulty of the math problems. An overwhelming majority of the 26

responses about games were positive towards games, including responses such as "...make games in the middle of the tutoring so kids won't give up." Only 2 of the 26 responses were negative, one of which asks for "NO mosaic landmarks or fifteen minute breaks." The negative responses only seem to be in relation to the fact that the mosaic games were mandatory, which indicates that students desire control over whether or not they play a math game. One student suggested "It would be better if it had some games when your [sic] done to relax your mind." Having the games at the end of a tutoring session means that they do not break the flow of problem-solving, but some students enjoy breaks. This leads me to believe that the games as breaks should be optional, but games should also be included as a "cool-down" exercise at the end of a tutoring session.

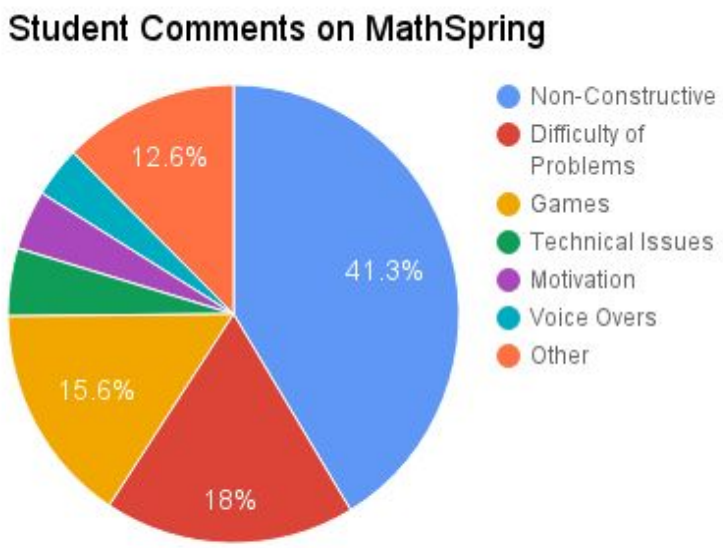

Figure 4.1: Student Comments on MathSpring Pie Chart

4.3 Results of Study 3

From observing the study on three different days over the course of four weeks I was able to get a sense of how the students were reacting to both MathSpring and the mini game breaks, as well as how I could improve the study itself in the future. In total, twenty-four (24) students participated

in the study, half were 7th graders and half were 8th graders. Eleven (11) of the 24 total students had the potential to get mini-game breaks. Over the course of the entire study, thirty-four (34) mini-game breaks were offered to the students in the test group, of which there were nine. It is unclear how many of those games actually got played. One problem that we ran into was that the computers provided by the school had popups blocked, and an outdated version of Flash, both of which are required to make the game breaks run smoothly. When I was able to see a student interact with a game break, it was clear that they enjoyed the game, but also that it disrupted the students around them. This was likely due to the small class size and configuration of desks in rows, so everyone could see what everyone else was doing. This was not all negative, as by the end of the study, even students who did not see games on their MathSpring could weigh in on whether or not they thought game breaks were a good idea. One student responded to a survey question about what they would like to see more of in MathSpring with the insight that we should "Add a more likely chance to get a game because kids gets stressed and anxious when they dont (sic) the game and other students do."

As is outlined in the study description (Section 3.3), students who had the possibility of receiving a game break prompt (in the experimental condition) had a 10% chance to see it after every problem. This proved to be too low a chance, and for the final day of the study was increased to 20%, but didn't seem to affect the outcomes much. Only six (6) of the 34 total potential game breaks occurred on that last day of the study, the other days all had 7-9 potential game breaks. This is likely just due to the random number generator. For any future studies on game breaks I believe that the best course of action would be to have the game breaks after 5-10 problems, so that the

students feel that they earned the break, rather than just having it randomly appear. Some of the students agreed with this sentiment in the survey and discussions that took place after the study.

There were twenty-eight (28) responses to the two short answer questions on the survey given after the study was complete. Sixteen (16) of those answers were to the question 'What would you like to see more of in MathSpring?' and the other twelve (12) answers were to the question 'What would you like to see less of in MathSpring?'. Of these total 28 responses, 11 were non-constructive feedback, 8 had to do with the content of the math problems, 2 had to do with breaks in general, 3 had to do with games specifically, and 4 were related to other parts of the program. All of the responses related to games were in favor of games, and two of them suggested that after a certain number of problems a student would be offered a game, rather than it being random. Responses related to breaks in general were also all positive. The responses related to the content of the math problems were mostly due to students viewing repeat questions in their tutoring sessions, or to wanting more topics directly related to their work in math class. The other responses ranged from the user interface of MathSpring to improving the hints system and doing away with timed prompts (ie. after a certain number of minutes in a problem being asked if they are stuck).

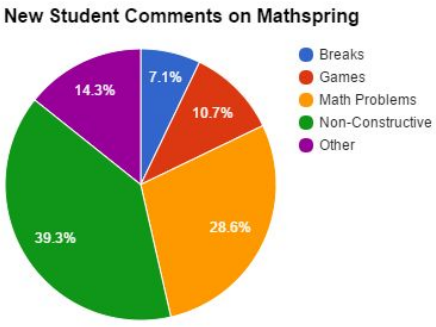

Figure 4.2: Student Comments on Changes Implemented to MathSpring Pie Chart

During the study, MathSpring would prompt students to report on their level of frustration and invite comment from the students on why they felt that way. By the last day of the study, 24

students had reported on their frustration, half were students who had the potential to get game prompts, and half could not have received any game prompts. Due to the small sample size and timeframe it is impossible to say the data gathered is conclusive. The students who had the chance to receive game prompts reported their frustration closer to the middle value, 3 on a Likert scale of not frustrated to very frustrated, and reported high levels of frustration less frequently than students who could not receive game prompts. However, students who could not receive game prompts (in the control condition) did report low levels of frustration more frequently than the students in the experimental condition.

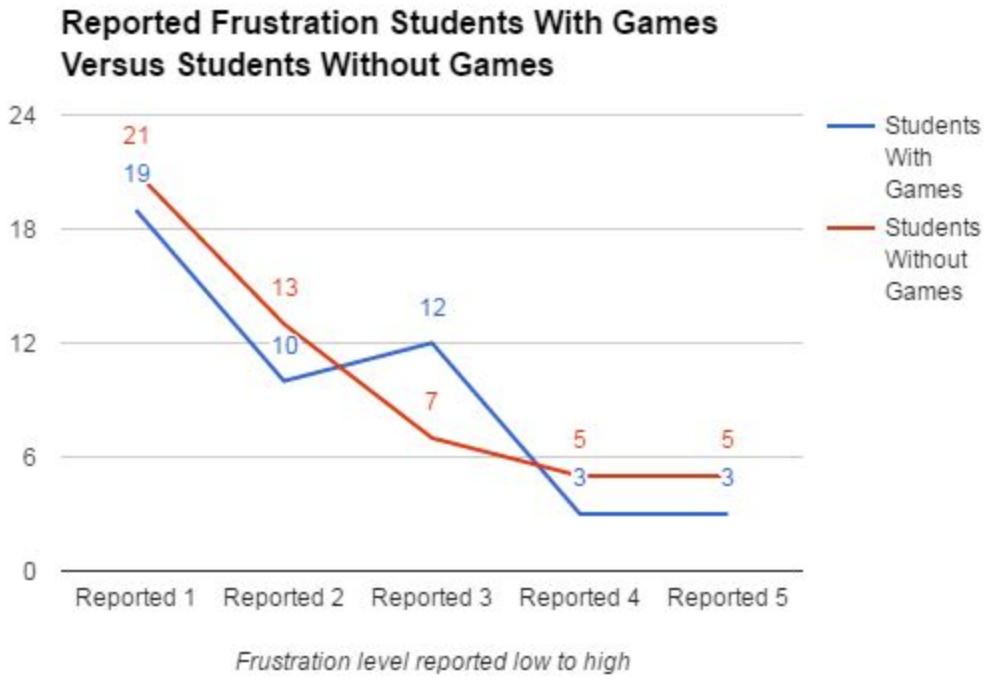

Figure 4.3: Reported Frustration of Students With Games versus Students Without Games

5 Discussion

The original question intended to be explored in this project was 'how can we improve MathSpring for Latinx students?' Specifically, I thought that I would be working on creating new options for the companion characters in MathSpring, including changing some of their dialogue to appeal to Latinx students more. This original prompt for the project was almost too broad to tackle. During the initial research for the project, I pulled from many sources which did not even end up cited in this final report on the project because of how drastically the project changed.

In an attempt to narrow the project's scope, I decided to focus more on the language aspect for specifically Spanish-speaking Latinx students who do not speak English as their primary language. Focusing on language was a choice that I made largely because I did not believe that changing the companion characters would have an impact that I could measure in the timeframe of the project. Focusing on specifically Spanish-speaking students was to further narrow the scope, as Latin America is a continent of many languages, and while Spanish is the dominant tongue Portuguese has a large presence as well. I am also much more familiar with Spanish than any other language (aside from English).

This is how I arrived at the translation of the word problems as one half of the project. The other half - inserting mini-game breaks into MathSpring - was born out of the preliminary research leading me down an interesting path. I read a portion of Dovan Rai's dissertation, in which she focused on games for math education, and had a small study where she had students use MathSpring with mini-game breaks. This study, combined with the work I had read on intrinsic motivation, led me to the conclusion that well-structured breaks in the math tutor that made use of math activities that were intrinsically motivating could alleviate some student frustration during use. While the game

breaks aren't directly related to improving MathSpring for Latinx students, I needed a portion of the project to be related to Interactive Media and/or Game Development. Half of my project was already going to be handled by myself and a Spanish professor. Also, the line of study of intrinsically motivating game breaks was intriguing.

In completing this project, I expanded my own skillset. Through interviewing David Yale about his experience with MathSpring, I learned to conduct and analyze a qualitative interview. I also learned to test with students in a classroom setting and see them react to my ideas. The study conducted helped me to gather and analyze both quantitative and qualitative data relating to my project in a way that I had not done before. The reactions of the students in the qualitative survey supported the concept of adding games as breaks. All of the responses that had anything to do with games or breaks were in support of them, especially as a reward or way to relax while studying with MathSpring. In the informal discussion with students similar sentiment was expressed. They even suggested different ways of integrating games - as rewards to be bought with points or after a certain number of problems. The fact that the students were so engaged with the idea supports my thought that games belong in classrooms, and that both educators and game developers should explore learning through play.

At the same time, many difficulties arose from the circumstances of this project being two projects in actuality, the fact that the team was just one person, and the limited resource pool I had to pull from. Finding students to test the translated math problems on ended up being impossible within the timeframe of the project. Finding students to test the game breaks was difficult, and when the study was performed the lack of control that I had over the study resulted in limited use of the data collected. Because of the way that MathSpring is programmed I couldn't implement the games

the way that I intended to, which resulted in a few surprises upon beginning the study, mostly that the students weren't getting game breaks frequently enough. All of the implementation also had to be done through two levels of disconnection from me, which is to say that I had to tell Professor Arroyo what I wanted implemented, and she had to tell one of the programmers at UMass. This made things slow and imprecise.

Some of the problems were unique to being a one-woman team. Mostly these problems ended up slowing down the project. When I got sick the project was not able to progress for a whole week. When I went to conferences the project also slowed down significantly. When I needed a sounding board to figure out how to proceed I often did not have one. I was limited to doing things within my own skill set, so I was not able to program new content effectively. Finally, being one person working on two projects of this scale means that the viewpoints explored are fairly narrow, most of them being my own views. I believe that I would have benefitted from working with a team, and that is the main aspect about this project that I would change if given the opportunity.

Fortunately, even with all the difficulties working on this project this past year, there was plenty that went right. I was unsure that I would be able to test the implementation of minigames, but I was. The results from the study to examine the game breaks also supported hypothesis and suggests that future studies could further the research. The translation project opens up a new avenue of study for the MathSpring team - determining if providing the translated problems help ELL students. Finally, I end this project with a handful of ideas to pursue in future research and creation, for both myself and the MathSpring team.

6 Future Suggestions

Due to the time constraints on this project, there have been many ideas suggested that could be picked up by a future project team to push educational games forward into new and greater territory. The first two suggestions are new math learning games that incorporate the math as a mechanic of the game, rather than having it be math problems with a point system. The first can be seen in Appendix 1, and is a game about fractions that uses stringed instruments to teach. The premise is based on the idea that when you shorten a string into a certain fraction, the frequency at which it vibrates is multiplied by the denominator of that fraction. Since the musical staves are just divided into eighths, it lends itself to teaching fractions. The second suggestion is a game that uses smoothies to teach ratios. The player would be running a smoothie stand and customers would ask for smoothies that have a certain ratio of fruit to liquid, and either a certain color or flavor. This game design can be seen in Appendix 2. The two studies proposed that were not organized could also be picked up by a project team in the future. These two studies answer the questions of whether or not break activities for students should be timed or emotionally triggered, and if there is a difference between students taking digital break activities versus analog, or physical, break activities. Both of these studies are outlined in Appendices 4 and 5 respectively.

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Appendices

Appendix 1: Mathemusic Design Document

The concept is simple: a guitar string that can be divided into different fractions by placing an object at a certain point. Just like a real guitar string, when the string is effectively shortened, the note it plays when struck changes. This is because the frequency at which it vibrates is multiplied by the denominator of the fraction it has been divided into.

- **Mathemusic** is a game exploring the relationship between fractions and music.
- **Audience**: 5^{th}-7^{th} grade students (could go younger or older, target range is students learning mostly about fractions in math class)
- **Art influences**:
  - Paper Mario/Yarn Yoshi
  - Stop motion animation
  - Office supplies
- Fraction markings placed along string (they will be at the length that the fraction would be, to enhance visual feedback of what a fraction is)
- Students will drag and drop an item (paperclip?) to the string at a fraction marking
- When the string is clicked it will act as if struck. It will play the appropriate note and the portion of the string that was struck will vibrate.
  - The vibrations will be at different frequencies depending on the note
  - The vibration animation will be a little exaggerated to give the players a sense of how the frequency of a note changes depending on the length of the string

- Notes will be explained as Do Re Mi Fa Sol La Ti rather than letters, tablature, or notation
  - This is how early music is taught and is easier to understand for students without a music background

Students will receive prompts and questions about the music. Here are **examples**:

- When you pluck the string at half the length, the frequency of the sound is doubled (multiplied by two). If you were to pluck the string at a sixth length, what would the frequency be multiplied by?
- When you pluck the string at one fourth the length, it is a Do that is two octaves higher than at full length. It is 16 steps higher than the full length. How many steps higher would a Do that is three octaves higher than the full length be? What fraction of the string would you pluck to make this note?

These prompts and questions should probably be simplified and shortened.

Appendix 2: Smoothie Game Design Document

Players are running a smoothie stand. Their customers will order a smoothie with a certain ratio of liquid to solid and a size (small, medium, or large) and either a certain flavor or a certain color. The students will then use measuring implements (mostly measuring cups) to fill the blender up to the right amount with the correct ratio of liquid to solid. This will help them to get a visual representation of ratios as well as give them some experience with real world applications of fractions (the measuring cups).

- **Smoothie Stand** is a game about ratios in the real world.
- **Audience:** 4th-6th grade students (or any students learning about ratios)

Appendix 3: David Yale Interview Transcription

David Yale Interview 9/16

[It should be noted that I didn't have my mic recording for the entire interview, and so for most of it I am only recording David's responses]

Transcription begins at 4:05

David Yale: I'm a PhD student at UC Santa Barbara

So, what's my experience teaching math. I would say… So I used to teach at-risk kids in San Francisco for about 5 or 6 years and I was like the math and science teacher, there were four of us at this school where we dealt with kids who had kind of dropped out or been kicked out of the system, this was kind of their last chance at getting a high school degree/GED. So I would teach those kids who had pretty much given up on academia as a route. You know, almost given up, on the edge. And at the same time I would tutor really high end math kids um, who are trying to get into colleges, mostly high school kids. I taught high school physics for about ten years, and along with that there would be every other year I would also have to pick up some remedial algebra class I would teach, usually the class none of the math teachers wanted to teach. It was like 'oh we have too many remedial algebra kids this year – Yale will you teach this class?' So that. And then in physics you end up

teaching a lot of math along with physics. You gotta teach the math to support the physics because they don't have it yet. And um, I guess I teach my son math. And I also still tutor math, still tutor a few people in math and statistics who are trying to get a better SAT score or get into a college program or something like that. And my son is ten and I've just sort of like been putting math everywhere in our conversations. Everything's a math problem.

[Question about experience working in this dichotomy between very low level math students and very high level ones]

Thank you, yeah, that's a great question. Well, y'know, there's definitely an SES element to it. So it's really easy to attribute the um the kids that- I charged a lot of money to privately tutor. So you kind of had to have a lot of money. There was kind of a self-selection going on there so it kind of amplified the difference for me about the impact of economics and also desire. There was a sadness that I felt. Like, y'know, I didn't have the language back then that I do now, but I really love Martin Sellegmen's (sp?) work on learned helplessness and Carol Dweck's (sp?) work about growth mindset, and some of Angela

Duckworth's (sp?) work about grit, there's all this like, educational psychology mindfulness that is really apropos in the

academic context, especially in math given it's, given that it's okay to say 'I suck at math' but not 'I suck at reading', y'know that weirdness. SO I wish I had the language when I was doing it to think about it that way. But mostly sadness, and y'know, wondering like how do you get a high school kid who's had a good 4 or 5 years of being beaten down by math failure let's call it, how do you get them to shift and say 'I'll give it a serious try' y'know, and then worse is that most – and this is my biggest pet peeve, and I don't know all math programs, but my biggest pet peeve with math remediation is that there's a mismatch between the age appropriateness of the presentation style and the math level that's being presented. There's an assumption that if you're learning fractions you must be in fifth or sixth grade. But if you still need to learn fractions and you're in tenth grade and the presentation for teaching you fractions is Barney on a see-saw, you're gonna be laughing at it, it's absurd. The kids are way more sophisticated than we even admit to ourselves as tenth graders and they need to see fractions in a context that's exciting for them, and I don't know what that necessarily has to be, but it certainly isn't Barney on a see-saw that would please a – I'm being facetious, but that would please a fifth grader, do you know what I mean?

[Question about experience with MathSpring]

Well yeah, I mean it's been limited to conducting the experiments. We've done, um, 2 multi day trials in 2 different classrooms, each classroom was, I think, four different classes. So, three days of four classes, so that's 12 and another 15 I guess. So, like, that many days of basically proctoring if you will, the experiment. And, I don't know how much you know about it, but that was the test to see if collaboration made it, had any correlation with performance or affect. We split the class in half and half the class would be occasionally prompted to collaborate with their neighbor and the other half wouldn't be and to see if there was some kind of analysis of that data. And so, go ahead

[Question about the makeup of the students in the study]

Um, I would say that they were um, somewhere in the 90s percent Hispanic, and um, lower SES. And they were seventh graders mainly seems like. And they were mixed gender.

[Question about his opinion on MathSpring]

Well, I love that there's actually- I think math lends itself really well to an AI computer individual thing, I mean I think math is brilliantly suited for that. And I'm really happy that there's an interest- that you guys have an interest in affect, does it work, what do the kids think about it, because math is

so often presented as completely, zero motivation at all, it's like 'you will do this' not 'why it's important' or 'hey lets get you excited about doing it' so looking at affect is extraordinarily important in math and in this context, so the fundamentals I do like about it. How the experiment is actually conducted- I dunno, I mean, not particularly, I have some ideas on improving it but um. That's sort of um. We'll get to that. I dunno, did you get a chance to look at the suggestions, my most recent suggestions I made on the there's an affect team running an agenda, I typed up a page of suggestions.

Ivon Arroyo: She didn't actually, I think that you can summarize those. Yes, I mean I guess I was hesitating because a lot of it has to do with the experiments themselves. And improving part of the experiments maybe but also the software. But please summarize those

D: I'll have to refresh my memory.

I: I can give them to her later, right

D: We can do both, I mean I'm sure I'll miss something or I'll add something but I'm available, Rachel, and if you need something clarified I'm happy to make it better. I think it's really important. Thank you

Yeah so um, I think all kids are different, and I think some

kids are like, really happy to have a chance to work independently on the software program, so that's probably, y'know, whatever, ten percent of the kids are gonna really be happy to have it. 80 percent of the kids are gonna be like 'yeah whatever the plan I'll go along with it' so they don't care if it's whole class, individual with computer, whatever. And then ten percent is like 'I hate this, I hate working on the computer with math, I don't like it, I feel isolated, alienated' or whatever their subjective experience is. SO I think that it's important to acknowledge that and even like ask for that, and wonder if, as an experimental protocol, what do you do with those kids that really just don't like that format? Do you force them to do the math online? Or do you give them something else to do and are like 'Fine, we get it'? I'm not really sure I have an answer for that but what I did notice was that there were kids who were just being tormented by doing this, and we're sitting there being like 'stay focused because you're disturbing your neighbors which is throwing off the experiment' and then, you don't want to get punitive and be like 'okay put your face down in your lap for the next hour' you don't wanna go there. I think it's something to think of as like, both as an experimental input as well as, humanity or dignity or something, what do you do with those kids. It might only be one per class,

but it seemed like it was like one or two per class that was just like just not happy with it. But at the same time there was one or two that were like 'oh thank god, freedom' y'know 'finally I get something that gives me what I wanna be doing' so it's not like it's intrinsically wrong it's just that all these kids are so different.

Yes. Yeah, I mean all of those behaviors were exhibited. I couldn't really know what their math skill was relative to the students. It's also hard to tell, was it that day? Did they have a bad experience right beforehand? Or is that who they are always with computers, or is it cause they're sitting next to Jon or because they're not sitting next to Jon or whatever, it's so hard to tell, mostly it was like any chance they got to have a problem with it and needing to raise their hand or needing to go to the bathroom or needing to plugin their computer or needing to change seats they just weren't like into it. And I would say that they didn't do the click through thing, that was another kind of kid, the kid who just hated it was basically doing everything they could not to look at it even it seemed like. Turning and talking to their neighbor or the teacher or moving around, versus the kid who just didn't want any attention it seems like and would just like 'I dunno what I'm doing' click

through, and maybe they wanted to see if they clicked through what would happen to their growth tree or pepper bush or whatever it was called. I think they were like gaming the system or just trying to see how the system responded to their input, not about math per se.

Okay, so.. Y'know I didn't sit and watch an individual student for any prolonged period of time, most of the time I was troubleshooting, so I'd go from one side of the room to the other. So with that caveat. What I noticed with the ELL students was that they couldn't understand my instructions or the teacher's instructions and when I noticed that there was a student that was getting help from a neighbor then I would like basically positive reinforce that neighbor for helping out like 'wow that's very cool for helping out' cause they were basically translating right. And then showing them how to comply with the instructions we were giving about getting into the program and. So they were just like slow and behind where the group was at, which is totally understandable. And I think.

I: From the beginning, logging in was that an issue?

D: Oh yeah, yeah because they didn't' even know they were just like. They were a step behind everything and so there was this lag and the lag would cause a bigger lag in doing things. So what usually ended up happening- it seemed to me, this is

anecdotal , it seemed to me like they would just sort of wait until the dust was settled around them and then somebody would help them do everything at once rather than step by step. That's just on the login part. Once the test started, I mean I felt so bad for everybody involved because the kid who was translating was gonna be distracted so their performance is gonna go down, and the ELL kid who's getting translation, well they either get it in which case they're grateful and they're gonna continue to work, or they didn't get the translation so what are they gonna do, sit there and look at this screen that's speaking in English which they can't understand, with words in English that they don't understand. I think, I think also, maybe this is revealing my racism or whatever, but there's also what I've noticed is that most of the ELL kids are, well we call them 'first generation' and so usually they were born and raised out of the country and they just got here within the last couple years, which is why their language skills are low, and they're- they don't really ask for help. They're surprised to be in school I think, especially at that grade level, based on my conversations with former students, former Mexican or Latino students, that you don't really go to school in seventh grade if you're poor, and most of the immigrants are poor.

I: One question- why do you say that they don't ask for help?

D: Yeah, like they just kind of sit there, it's like they don't wanna rock the boat, they don't wanna be a problem, so they don't ask for help they just sit there and let everything happen and they just try to blend in without like calling attention to themselves.

Oh yeah, definitely.

I just wanna be really clear, I'm not talking about all ELL students, because that's a label that gets attached based on language test performance, I'm talking about first generation students. I think that their emotional experience is um shame and embarrassment, and probably a little bit of ah, fear, y'know. I would say mostly shame, like, they're probably already teased for being 'fresh off the boat' or whatever the sort of cut down is, because there's definitely a cultural shift between first and second generation immigrants, and there's a like a pecking order. And it seems to me, like this is sort of a gross over generalization, but it seems to be like this sort of hierarchy of like coolness or something, especially in kids, I mean I can't. I mean even when everybody's homogenous there's this cruel pecking order that seems to be established. And then they have this other layer on top of it, y'know, which is like, not knowing how things work, not knowing how school works, not

having the right clothes, and their parents not even realizing what the right clothes are and there's so many layers I think to what's going on for these first generation students, it's um. I think it's just one of the most beautiful things is to see one for these guys succeed because the odds are so stacked against them culturally and like sociologically. Anyway, I'm getting off topic.

Yeah, I um, I speak to them in the worst possible broken Spanish I can muster, and um, let them see me be vulnerable, and trying to speak Spanish and that somehow gives them permission to speaking whatever limited English they have. I think showing them caring and basically being proactive, and not just like expecting them to follow along because I said the instructions but to go along and reach out and say 'how's it going for you' and maybe, oftentimes there'll be somebody who can help translate, and trying to sit them next to other kids who they seem to be comfortable having that translation experience or relationship with, trying to find little ways like that to make it more possible for them to get up to speed. But showing care, is, I think, the biggest thing. Like 'you belong here' kind of idea.

I: Can you give an example I wonder? Like, pretend you have a

kid who's ELL and he's totally stuck. What would you say in your own words?

D: Uh, on the MathSpring or in my remedial math class?

I: Say on the MathSpring

D: Well, I would, first I would empathize, they're totally stuck and I'd say uh, in the best Spanish I could muster, I would say I understand it's difficult because I can't' imagine what it would be like to take a test in Spanish. It's amazing that you're even getting this far, that's pretty cool.

I think it's a tall order because then you're asking MathSpring to be something for everybody, and that's a lot to ask, to be something for everybody. But if you wanted to make it better for ELL students, well I think certainly having a Spanish version would be, at a minimum. Just that alone would sort of like level the playing field for the ELL students, and I think if you really wanted to go for it, you would have it be in sort of Spanglish version where like the question that gets said once in Spanish and then once in Spanglish and then once in English or, just sort of like give it to them how they know it, how they can figure it out, and then show it to them how it would be if they weren't ell so they could actually get stronger in their English as they go along.

Well, so yeah, the look and feel of the interface, I think needs

to be um, y'know, like really thought through for age-appropriate. And I almost wish that um, that there was some agency that kids could have in choosing the look and feel, like almost like a skin if you know what I mean. If the kid loves soccer, then the whole thing they would choose the soccer skin, and their experience would have a soccer theme for everything. Or if they like pokemon still, okay fine, pokemon skin, or if they like music then music we do. Like, there could be like, that's that age-appropriate spread in interest-appropriateness.
I: That's not just for the character, right? IS it for everything?
D: I would say everything, cause I can ask the same math question in the context of how to make shoes, how to play soccer, or how to go to the moon, I can get the same math question, math concept learned, right? So why not just do it with everything? Cause if I'm interested in soccer, then I'll pay more attention to the question if it's about soccer than I will if it's about how many tables there are in a restaurant. I think, that's how I have always reached my students, and how I've always tutored, I always say 'what interests you?' and then our entire math experience and our entire physics experience is about that topic, that's what we look at because the math is in

every topic, so why not make it. Why not tailor the question for their interest? Then it matters.

I: So, one question, I know that you also have kids that are about that age, and so if you think of seventh grade, eighth grade or even sixth grade, how would those interests change? Is there something general that

D: Well, obviously you can't do everything

I: Of course not. So you mentioned pokemon and soccer are those very popular themes? Are there other themes or interests that students might have that you know of?

D: Absolutely, I mean … if this were my baby and I was gonna go do this, what I would do is I would just go survey teachers and ask them 'hey, what are'- I wanna have like five skins for MathSpring for the kids to choose from, or ten skins or however many you feel like is not- I mean obviously adding a skin on is a lot of work so you don't wanna kill yourself with work by adding too many skins but whatever you feel like you could do,, four skins, ask the teachers just like poll them 'what are your kids interested in?' and then tabulate it and find the top four interests that are kind of gender diverse and say 'okay we have these two interests are kind of girl interests and these are kind of boy interests' and then when the kids start the program it's like 'you get to choose a skin' and then every so often,

every so many right answers you get to change the skin, but not whenever you want, just at certain moments, otherwise they just play with skin changing all the time. But I think you gotta give kids agency, you gotta make it interesting, but you can't let them screw around the whole time so there's a balance of like how to achieve that, so. I'm just making up soccer cause if we're talking about latin culture, latin boys, soccer's the thing, right. You could add in cars, and for the girls um I don't really know but it might be, I don't wanna be like gender stereotyping too much, I don't really know what the girls would be interested in, but there must be something that's' pretty common. I know that in latin culture, if you wanna focus on that, I know that the quinceanera is really important to them, so maybe there's like a quinceanera culture or something like that.

I: Parties, dresses, that sort of thing

D: Parties, yeah I guess, but not Barbie style but like, rihanna or whoever the hot- you know what I mean? It's gotta be- if I put myself in the shoes of a seventh grade girl especially, like they wanna be 15 and cool and pretty, right? So they're always trying to be older, and we're trying to always keep them down like 'don't rush it enjoy being twelve! It's fun! It doesn't last

t forever!' so there's like that tension. Do you know what I mean or am I crazy?

I: Yeah, I understand

D: So anyway, yeah I would survey teachers and ask them. Cause they know what the kids are doodling on their binders. They know.

I: Do you still have a relationship with Beth Lindley (sp?)? I'm wondering if some of the teachers that we've – we would just email them or something like that and ask them.

D: Yeah, I mean I think so, I think that would be a really effective. I could definitely do that. I think a phone call would be good too, if you created a survey, once you've got a few ideas. The easier the better, because teachers are swamped, so the easier you make it on the teacher the better.

I: Yes, keep going

D: Um, well, one of the… there's two stakeholders that are really key, one is the student learner and the other is the teacher. So, a tool- feedback is amazing, feedback that's like intuitively obvious or available for both the student and for the teacher, and they want different kinds of feedback. The feedback the student gets is 'hey y'know we noticed that you spent' and I dunno that this is the answer but just as an

example ‘we noticed that you spent two minutes on that problem before you answered it, and you answered it with this answer choice, which wasn’t wrong, and then you answered it with this one which, y’know, is really good, maybe you thought about the math problem this way’ or maybe like ‘that’s the fifth problem in a row that you’ve answered correctly on the second choice wondering what approach you’re taking to answering would be better for you’ I mean I’m not-I’m just sort of fishing out like, that sort of feedback for a student might be really useful, not a huge dose of it, but just a quick blip like ‘we noticed this’

I: So you’re talking about awareness about what has been going on, so you’re suggesting that maybe students don’t reflect or realize what they have just done…

D: Yeah, I mean I’m trying to think of- I know that like, if I wanna get good at something I’m gonna get a coach, and MathSpring is kinda like a coach, and what I want a coach to tell me is where I’m doing good and where I need to work harder because I can’t tell because of my subjective experience, I need an objective- I need another pair of eyes, and that’s what MathSpring can be for them, it can be like ‘hey, this is what I’m noticing, this seems to be where you’re good and this seems to be where you need improvement, here’s a couple tips, maybe

take your time maybe ask yourself these two questions: am I hurrying it or am I missing data or whatever, or am I not asking for a hint' there's all kinds of data that we can show the kids is happening in that moment. That's just a thought. And then, for the teacher, um, I think… really easy to understand feedback on how the students are performing. And, I've said this to you before Ivon, and I've tried to understand it better, but I have a hard time reading the feedback in its current incarnation. Some thinking about the feedback, cause I think if you want teachers to really use this- if you want this to be something that teachers could, y'know, would wanna use in their classrooms, giving the teachers access to what's going on would be fabulous and being able to assign two problems to take home at night and knowing if the kids did them or not would be amazing. But that's always the challenge.

I: Can you tell us more about that, what kind of-yeah I mean very very simple, something that wouldn't take a lot of time that they could understand, what- give me a thought of how you see that.

D: Yeah, happy to, which part, I said two different things, one was homework and one was teacher reports

I: Teacher reports

D: Okay, so maybe how many of the kids in the class have, what's the distribution of kids that have shown adequate progress on –or whatever the language is- on this topic, y'know adding fractions with the same base, and you could just have it be simple it would just be like 85% of the kids are above standard on that okay cool. So we're solid on those topics, and so you could quickly see where the program thinks that the class needs more work, and if you drill down then you can see which of the kids, what 15% aren't doing good on adding fractions of the same base and then you could easily assign those 15% of the kids remediation on that topic, so that they would have that homework tonight, so it would be like you could quickly note-notice where the holes are, cause the holes are gonna be all over the place right, so you could quickly notice where the holes are and then give individualized remediation for your kids and the program is keeping track of that for the teacher. So the teacher doesn't have to worry- it lightens the load on the teacher to keep track of 30 kids each with a slightly different remediation that they have. Does that make sense?

I: Yes, that's an excellent suggestion I wanted to hear you say, thank you

D: Yeah no problem

[Asking about what the teacher interface is currently like in

MathSpring]

D: Yeah I would invite you to go, yeah but I will tell you this- it's very confusing for us

D: Yeah y'know I think the biggest, the overriding mantra that I hope everybody really embraces is that, like, it's hard for the kids to sit down and do the math, they're so sweet and they're so nice and so helping us to do this but, they need motivation to do it and it can't be like the teacher just dictating 'this is what we're doing you're gonna be learning math' there has to be some hook in the program, either in the MathSpring program or in the teachers classroom, there has to be some kind of hook, and if you could figure out a way to make just doing the MathSpring more interesting as compelling as a video game or a music video, if you could try to achieve the compelling like 'yeah I wanna be doing this' if we could achieve that if we could look to that then all the other stuff would melt in difficulty y'know, it would just be gone because kids would be trying to do it. I think really looking and listening to what- not pandering-not making it a video game not pandering to the lowest denominator but like really honoring that yeah they're sophisticated creatures that live in our society and they wanna be- they have iphones and they're not sheltered and hidden away,

so we gotta motivate them, so whatever we can do to make that happen, a lot of stuff- a lot of problems will disappear for teaching math.

[Thanking him and wrapping up]

I: Thank you, it was awesome David

D: Thanks guys

I: I'm so glad we sat down to just listen to you

D: Yeah, and I think there's some really interesting stuff in educational psychology- there's so much- as a parent I'm always reading this stuff, and I think it's so appropriate to what you guys are working on with this software, it's so interesting how we can use these findings to help kids achieve their potential, so I really encourage thinking along-looking to psychology as ways we could weave that into what we're up to. Okay thanks so much for caring guys!

[Goodbyes and hanging up]

Appendix 4: Proposed Study: Observing Affect in Response to Emotionally Triggered Break Activities

To determine whether or not these breaks alleviate negative emotions, a study will be performed. This study will be run similarly to Study 3, but not simultaneously. It will be run after the conclusion of Study 3 in different classrooms, and will still have the affective response system active. Students will use MathSpring as normal, and when they report certain negative emotions (ie. boredom or frustration), they will receive an option to do a math activity. These activities will vary and could be digital or physical, depending on classroom resources. Their affect will be recorded as normal in the MathSpring software. There will be a control group of students who receive the timed break activity prompts, rather than the emotionally-triggered ones. The students who receive the timed activity prompts and those who receive the emotionally-triggered ones will be randomly selected, 50% of the students will receive timed prompts and 50% will receive emotional prompts.

The outcomes of this will be recorded and analyzed the same way as in Study 3 (see Section 3.3). The expected outcomes are that the emotionally-triggered break prompts will have a larger effect on a student's emotions than the timed break prompts.

Appendix 5: Proposed Study: Observing Difference in Effect of Digital vs. Physical Break Activities

This study will determine whether or not there is a significant affective difference between students who have break activities on the computer and students who have physical break activities. A physical break activity is just a break activity not done on a computer. This study will be run after the conclusion of Study 4. It will maintain the affective response system. Students will use MathSpring as normal, and after a certain amount of time, but in-between problems, will receive an option to do a math activity. Half of the students will receive prompts for physical math activities and half digital. Their affect will be recorded as normal in the MathSpring software. The students who receive the physical activity prompts and those who receive digital activity prompts will be randomly selected, 50% of the students will receive physical prompts and 50% will receive digital prompts.

The outcomes of this will be recorded and analyzed the same way as in Study 3 (see Section 3.3). The expected outcomes are that the physical activities will have a larger positive effect on a student's emotions than the digital activities.

Appendix 6: Survey for Study (Section 3.3)

In English

Do you like your math class?

Do you prefer interesting math topics even if they are more difficult?

When solving math problems, do you often give up before solving them?

Does solving math problems make you feel frustrated?

Do you get anxious while solving math problems?

When you work on homework, do you do it all at once or do you take breaks?

Do you think that you learned a lot using MathSpring?

Did you enjoy using MathSpring?

(Open answer) What would you like to see more of in MathSpring?

(Open answer) What would you like to see less of in MathSpring?

En Español

Te gusta la clase de matemáticas?

Te gusta temas de matemáticas más interesantes, aunque son más difíciles también?

Cuando resuelves los problemas de matemáticas, dejas de la problema frecuentemente?

Te frustra los problemas de matemáticas?

Te sientes ansioso cuando resuelves los problemas de matemáticas?

Cuando haces la tarea, haces todo en un tiempo continuo o tomas unos descansos?

Piensas que aprendiste mucho por usando MathSpring?

Disfrutaste usar MathSpring?

(respuesta en párrafo) Qué querías ver más en MathSpring?

(respuesta en párrafo) Qué querías ver menos en MathSpring?