# Creating Computer Simulations In Middle Grades Mathematics: A Study of a Technology-Integrated Statistics Curriculum

by

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Creating Computer Simulations In Middle Grades Mathematics: A Study of a Technology-Integrated Statistics Curriculum

Dissertation directed by Associate Professor David C. Webb

## Abstract

This study examines two weeklong implementations of technology-enhanced mathematics units. Pre and post-survey data, student interviews, audio and video recordings of classroom sessions, and participation log data were collected and analyzed using quantitative and qualitative methods. Constructs measured included self-efficacy in mathematics and computers, triggered and maintained interest, future pursuits, and engagement.

Survey constructs were verified using factor analysis procedures, and t-tests and effect sizes were calculated for pre and post-survey differences of means. Further analysis using ANCOVA and mixed ANOVA procedures examined constructs and sub-populations flagged as potentially having statistically significant differences of means. No statistically significant differences were found between pre and post-survey means for any construct or population of students. Students reported high self-efficacy and interest in both mathematics and computer use overall on both surveys.

Analysis of interview and observation data found evidence of students' interest states shifting from triggered to maintained situational interest during the course of unit implementation. Students with repeated exposure to the Simulations in Statistics units were more likely to show evidence of transitioning interest states. Analysis of participation logs showed that, on average, students were highly engaged throughout the units. Engagement rates did not differ by gender, but the nature of engagement did. Female students engaged in more collaborative behavior, while male students engaged in more independent work and off-task behaviors.

Two teachers simultaneously implemented the units in two separate computer labs. The learning environments in these two labs were different: one emphasized collaborative work and student self-directed use of online wiki and tutorial resources; the other teacher did not. In the collaborative focused lab, a larger percentage of behavior was on-task for all students, especially female students. The learning environment was critical to the engagement of female students.

Latino/a students reported lower self-efficacy beliefs than white students especially in mathematics. Participation in these units gave students the opportunity to develop new self-efficacy beliefs in math and computer use in this context.

These findings inform research efforts to increase interest and motivation for women and people of color to pursue STEM related careers.

## Dedication

I dedicate this work to my family.

Thank you to my Mom and Dad, Sandy and David Sekeres, for always believing in me and offering words of encouragement and support when I needed it most. I love you both so much.

Thank you to my husband, Steve Marshall, for his support and the extra time he spent with our children when I was busy with my studies.

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And thank you so very much to my amazing kids, Travis, Garrett, Jesi, and Logan. I love you more than words can express. You were understanding and encouraging when I had to spend time working on my studies. I know you are looking forward to my graduation almost as much as I am. Then perhaps you will have a more "normal" Mom again… whatever that is!

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Thank you to the wonderful and dedicated teachers of North Middle School[1] who opened their classrooms to our project, attended and presented at the summer institutes, and agreed to go on a design-research journey with me to develop and implement the statistics curriculum studied in this work. I couldn't have done it without your help.

[1] Pseudonym

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# Chapter 1. Introduction and Rationale

## Introduction

Science, Technology, Engineering and Mathematics (STEM) fields provide many opportunities for employment. The need for individuals knowledgeable in these areas is ever increasing (Bureau of Labor Statistics, 2011). In these same fields, women and racial minorities are underrepresented (Hill, Corbett, St. Rose, & American Association of University Women, 2010). New STEM teaching approaches and tools are being explored for their potential to disrupt the continuation of the existing inequities. As an approach to address these inequities, the Simulations in Statistics (Sim-Stat) study presented in this dissertation examines a program where students use simulation technology as a tool to help solve reality-based problems and learn statistics. This dissertation details how this study examines the engagement, participant structures, and interest development of the 8th grade students in a rural middle school during the implementation of technology-enhanced instructional units for statistics.

## Background

In the current economic climate, securing employment can be difficult in many fields, but much less so in computer science, computer software engineering and programming, and other technology-related fields. According to the Bureau of Labor Statistics (2011), job growth should be greater than average in these fields with an increase in job openings of 20% or more between 2008-2018, and more job openings than job seekers. Paradoxically, while demand is increasing, there is a steadily declining interest in computer science, especially for women (AAUW Educational Foundation, 2000; Ashcraft, Blithe, & National Center for Women &

Information Technology (NCWIT), 2010; Corbett, Hill, & St. Rose, 2008; Margolis & Fisher, 2002) and African American and Latino/a students (Eisenhart & Edwards, 2004; Margolis, 2008). This is a phenomenon unique to computer science even when compared to other STEM fields. As Caroline Hayes (2010) writes,

> A substantial and persistent drop has occurred over the last 20 years in the representation of women among computer science undergraduates and computing professionals at a time when the proportion of women has been steadily rising in all other STEM fields. This trend is more worrying because it comes at a time when overall interest in computing for both men and women is down, yet a strong and creative information technology workforce is needed for competition in the global economy (p. 43).

With a shrinking pool of female, African American and Latino/a undergraduate computer science students, the representation of women and people of color in computing professions is in serious jeopardy. Furthermore, it is not just computing professions that require computational thinking[2] (Wing, 2010) and technology skills. From the corporate world, where "big data" are used to do market analysis and forecasting, to the scientific world, where computational models and methodologies are used to make advances in science, we are in an era where computational thinking skills and computing fluency are required by most professions.

To help address the gap between the number of individuals studying technology and the number of individuals needed in the work force, we need to develop and utilize new ways of presenting computer science material. Introductions to technology as a tool for problem

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[2] The term *Computational Thinking* was coined by Jeannette Wing and later defined as, "[T]he thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent [CunySnyderWing10]" (Wing, 2010, p. 1).

solving must begin at an early age; elementary and middle school students are capable and interested in technology when it is presented in a way that is accessible and authentic. By having students design and create their own computer simulations and games, we have seen how technology as a tool becomes more interesting and increases the perceived value and applicability of computer science for many girls and people of color (Basawapatna, Koh, & Repenning, 2010; Basawapatna, Koh, Repenning, Webb, & Marshall, 2011; Marshall, 2011; Repenning & Ioannidou, 2008; Repenning, Webb, & Ioannidou, 2010; Walter, Forssell, Barron, & Martin, 2007).

As a part of a 3-year NSF funded iDREAMS project, **Scalable Game Design** (Ioannidou, Repenning, & Webb, 2008; Ioannidou, Repenning, & Webb, 2009) the *AgentSheets* end-user programming tool (Repenning, 2000, 2011; Repenning & Ioannidou, 1997, 2001; Repenning, Ioannidou, & Ambach, 1998; Repenning, et al., 2010) and supporting curricula have been implemented in middle school classes in several states. *AgentSheets* is an object-oriented authoring tool where users literally drag and drop portions of if-then statements to create computer programs games and simulations. Students are able to focus on the design and creation of their project at a high level without the steep learning curve of a traditional computer language such as C++ or Java. This frees the students from having to focus on the exact syntax of a computer language, and instead allows them to concentrate on the semantic and design aspects of making a game or simulation.

The approach of the *Scalable Game Design* curriculum using *AgentSheets* has met with great success in middle grades classrooms. During the first two years of the Scalable Game Design Project approximately 45% of the over 4000 student participants were female and 56% of the participants were from racial minority populations. According to Ioannidou, Bennett, Repenning, Koh, & Basawapatna (2011), most of the students across ages, gender, ethnicity and geographical location indicated that they were interested in continuing to study technology.

While the majority of the classes using AgentSheets and the Scalable Game Design curriculum were technology classes, teachers in content areas such as mathematics, science, Spanish, arts, and social studies, have also implemented modified versions of the game design curriculum to address discipline-specific goals. This project focuses on one school where teachers used the *AgentSheets* software in mathematics classes during statistics units.

**My Interest In the Topic**

My interest in gender inequity in STEM fields began when I was finishing my bachelor's degree in mathematics and psychology. As a blonde cheerleader with knack for mathematics, I enjoyed being a blend of seemingly contradictory components. I was not alone in my interest in disrupting expectation. My fellow female classmates in advanced mathematics and I (few in numbers compared with the men in our classes) liked breaking with tradition and challenging conceptions of what was expected and "acceptable" for women. Yet this came at a price. For others to take us seriously, we felt we had to be more prepared, more knowledgeable, and challenge the preconceived notions formed on first impressions. The additional pressure to prove oneself could explain part of the gender imbalance I saw; still, I began to wonder why there were so few of us.

I had done well in my coursework and, near the end of my undergraduate work, had been invited to attend a meet-and-greet recruiting weekend for prospective graduate students in mathematics at the University of Arizona. I found myself surrounded by mathematicians, and future mathematicians, socializing around a pool in the Arizona desert. The conversations went well and I advanced to the formal interview round. The final round of interviews was to be in various professors' offices the next day.

I came to my interview early, dressed professionally, and feeling confident and ready. The interview began with the usual small talk and then, in what was a pivotal moment to me, although certainly forgettable for the professor, I was asked what in the field of mathematics I was interested in studying. Instead of ring theory, or algebraic topology, or even a more general, "there are so many areas in math that I love, what do you study?" response, I shared my insights as a female member of an almost exclusively male field. I replied that I am interested in why so many young women choose not to study mathematics. Why so many of girls say that they hate math and that they are no good at it. In my classes in the math department, why were there so many seats filled by men and so few by women? Why was this the exact opposite in my classes in the psychology department? What in their schooling, or the approach to what was being taught, or in their lives outside of class, was leading women away from the subject that I found so logical and challenging, beautiful in its desire for simplicity, a pure representation of ideas in variables and symbols?

The professor's response was short and blunt. He simply stated, "That does not matter." I tried to convince him that it did, that it mattered deeply. That among those students turning away from the subject could be great mathematicians who could bring new ideas and life into the subject, people who could be more educated citizens using math in their daily lives, and those who could have a greater appreciation for his work. My argument fell on deaf ears; I was clearly in the wrong department. I had spoken to my real interest, shared my curiosity and passion to find reasons for the gender discrepancies I saw in the STEM courses I was taking, only to find that this was not of importance to the field of mathematics.

This experience set me adrift. Perhaps mathematics was not for me. I did not attend graduate school that year. Instead, I took a job as a consultant / systems analyst with a large firm. It was there that I had an opportunity to see how corporate America teaches STEM subjects.

When I was hired, I was an off cycle hire, meaning that no one else was newly hired at the same time in my office. Each day I arrived and worked alone in a small room to complete my supply of "green books." Green books (called this because they were green in color) were training manuals for COBOL programming. I was to study the green books according to a given schedule and take the accompanying tests. What I did not finish at work was to be taken home. The tests were not externally graded or checked, nor were there any reteaching opportunities other than re-reading the same green book just completed. All training manuals were to be completed before I attended the two-week training in a facility outside of Chicago.

In the training classes, all participants were dressed in their business best. There was a strict dress code that included suits and ties for men and suits with skirts, hose, and heels for women. Even in this off-season time there were several hundred students participating, mostly from overseas, and mostly men. Women were definitely in the minority in the group.

The training started with large lecture hall type presentations and then we broke into work groups in various computer lab facilities. We were given tasks to program and were ranked on how efficiently we went about the work. Those who competed quickly and correctly were given a higher rank. If you asked instructors for help, your ranking was lowered. I was way out of my league. Many in the room had majored in computer science, unlike me who had taken one programming class, and read a few green books! The classes were structured in such a way that there was no collaboration, no sharing, and no way to benefit from the knowledge and experiences of others in the class.

It was relatively easy to see where you ranked based on the pace at which the higher-ranking programmers were given new tasks. At the end of the training institute, each person was assigned one of three rankings. Although I do not remember the names, I do remember that mine was not the top ranking. When I arrived back at my home office, I was greeted by the secretary, who looked over my paperwork and said, "Oh… we have never had someone with a ranking this low." *Great*, I thought, *nice way to start my career*. I also thought there has to be a better way to teach computer programming.

I learned a lot over the next two years and got much better at programming. In the end, it was the 80-hour weeks and travel schedule, not the tasks, which eventually drove me to end my employ with this firm. I began to consider how math and technology is taught in schools. I wondered if the way in which it was taught was contributing to the gender discrepancies I saw in school and on the job.

I returned to school for a master's degree in elementary mathematics education. If I were going to have any effect in turning the tide, or understanding the reasons for the turn away from math, I was going to have to work with young girls - before they made up their minds. My driving question became, at what point do kids shut down on mathematical thinking and why? How far back are those seeds of self-doubt in mathematical ability and interest in technology sown? I believed that if I was going to have an impact on the number of girls interested in math and technology, I was going to have to start early where girls are first making decisions about whether or not they are "good at" STEM subjects. I also felt that there had to be a better way to teach technology, a way to relate it to mathematics in a way that makes students understand what a powerful tool technology can be and how applicable both mathematics and technology are to real life questions.

Over the next few years I got a chance to try out some of my ideas as an elementary teacher, managing elementary and secondary computer labs and teaching high school mathematics and technology classes. I found that I could help empower girls by allowing them to see that they could be successful in, and enjoy, STEM content. Though I felt rewarded in reaching a few in my classes, I wondered about a more systemic approach to math and technology education that may work to disrupt the current gender imbalances.

I decided to return to school to research the gender discrepancies in STEM fields. At that time, information technology was, and remains, the forerunner in gender inequity (Ashcraft, et al., 2010; Salomone, 2003), and the numbers of women and people of color are actually dropping (AAUW Educational Foundation, 2000; Rosser & Taylor, 2009). I find this curious. Computer science is a relatively newly defined field and originally it was considered a “women’s job”, as it was related to clerical and secretarial duties. How did this field get masculinized? How do women find themselves on the outside looking in on a field that should have no gender limitations?

I have once again been charged with finding answers to those questions formulated so long ago in that professor’s office and defending why I believe it is terribly, vitally important to know how and why children’s enthusiasm for learning becomes trepidation, especially in STEM areas. I am interested in why so many young women choose not to study math and technology. In elective classes in the computer lab, why are there so many seats filled by boys and so few by girls? Why are the numbers of women enrolled in computer science actually dropping? What in their schooling, or the approach to what was being taught, or in their lives outside of class, is leading young women away from these subjects? Are there new approaches to teaching these subjects that would lead more young women and people of color to consider STEM related fields?

These questions could define a career of research. I have narrowed down my interests to make a first foray into the area through my dissertation.

**Research Questions and Claims**

In this study, I take a deeper look at the motivational aspects of end-user programming and development (Jones, 1995; Lieberman, Paternó, & Wulf, 2006; Nardi, 1993) and its applications in content area classes. I am curious about any differential effect by gender of this approach to teaching (integrating technology in mathematics) on students' interest in continuing to study technology and mathematics. In addition, I examine whether students with repeated participation in the technology-enhanced statistics units have more fully developed interests in mathematics and/or technology that could lead to future study and STEM careers. The research questions I address in this study are:

1. What are students' current levels of interest and self-efficacy in technology and mathematics?
   1.1. In what ways does interest development differ for students with repeated experiences using the *AgentSheets* software? (i.e. one, two, or three years of participation).

2. How does the implementation of technology-enhanced mathematics instructional units affect students' engagement?
   2.1. How does engagement differ by gender?
   2.2. What participant positions are available to students throughout the AgentSheets units?
   2.3. How do students take up the available participant positions?

These research questions will work to support or refute my claims:

Claim 1: The Simulations in Statistics units we developed and implemented help transition students' interest levels in technology and mathematics from triggered to maintained situational interest over time.

Claim 2: Students' social addresses are not good indicators of their level of engagement, interest, and participation in these activities. Though the kind of engagement and participation may vary by social address.

## Chapter 2. Theoretical Framework

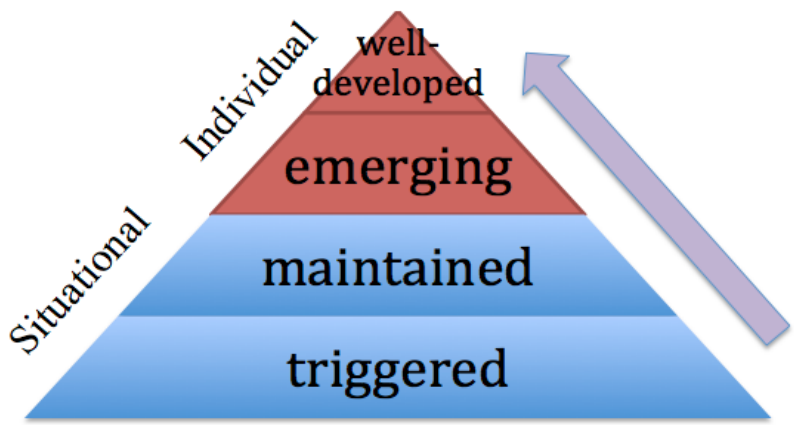
The potential for technology-infused learning to engage and motivate learners is great. Technology-enhanced curriculum, where students design and create simulations from scratch to address authentic problems, has been shown to engage both female and male students in learning both the content of the simulation and the related computational thinking skills necessary to plan and program it. Unlike the more traditional focus on abstract learning, providing students a contextual basis for applying mathematics and technology has been linked with more student interest and motivation (Forte & Guzdial, 2005). This may be especially true for female and racial-minority students (Eisenhart & Edwards, 2004). To specifically address this, Peckham et al. (2007) suggest using "interdisciplinary studies in problem domains of clear benefit to society" to introduce computer science to a diverse student population. They highlight the importance of aligning the program with the needs of the target population; once female and racial-ethnic minority students are in STEM classes, continued interest in the subject can be sabotaged if actual classroom practices are more relevant to white male students (Peckham, et al., 2007).

In a study conducted by Walter, Forssell, Barron & Martin (2007), the authors found that programming in the context of game design can be of interest to a broad range of students, not only those who already are engaged in technological activities. In Walter et al.'s (2007) study, the students programmed games from scratch and exhibited a high degree of engagement in the activities. The "next steps" presented by the Walter et al. (2007) study include "Further analysis and research should seek to uncover details of students' experiences, and whether this influenced their motivation to continue or not" (p. 2740). In other words, the students showed situational interest but it is unclear if this interest was ongoing.

**Interest Development**

One way to conceptualize motivation to continue engaging with a particular kind of task is in developmental terms. Hidi & Renninger (2006) offer a model of interest development useful for this purpose. The four-phase model of interest development described by Hidi & Renninger includes triggered situational interest, maintained situational interest, emerging individual interest, and finally well-developed individual interest. See Figure 2.1 for my graphical interpretation of this model.

**Figure 2.1 Hidi & Renninger's Interest Development Model**




Situational interest is "sparked by the environment" and externally supported (Hidi & Renninger, 2006, p. 114). Situational interest moves from *triggered* to *maintained* through learning environments that rely on personal and meaningful activities such as project-based learning. Mitchell (1993) refers to what Hidi & Renninger term *triggered situational interest* as "catch", as in catching someone's interest, and *maintained situational interest* as "hold", as in holding someone's interest. Individual interest, on the other hand, is typically self-generated and the student has a "relatively enduring predisposition to seek repeated reengagement" with the subject matter (Hidi & Renninger, 2006, p. 114). Barron (2006) refers to the individual interest phase as self-sustained learning where the student is involved in "independent pursuit of knowledge" (p. 194). Individual interest moves from *emerging* to *well-developed* when the student has positive feeling toward and values the subject and knows considerably more about it than in the emerging phase. In this study, I ask: Under what circumstances and for whom does participation in simulation design and use support the transition from triggered to maintained situational interest? Furthermore, the proposed study will examine the relationship between engagement in mathematics and computer simulation design and interest development that could lead to future STEM careers for students.

The President's Council of Advisors on Science and Technology reported that we must "*prepare* students so they have a strong foundation in STEM subjects" and "we must *inspire* students so that all are motivated to study STEM subjects in school and many are excited about the prospect of having careers in STEM fields" (President's Council of Advisors on Science and Technology, 2010, p. iii). With this as our charge, to excite, inspire, and motivate students to pursue STEM careers, then student *interest* in STEM becomes the focus as much as the STEM *knowledge* and preparation students gain in schooling.

Individual interest in a subject from an early age has been shown to significantly increase the chances of completing a STEM-related degree and lead to pursuit of a STEM-related career. Tai et al. (2006) conducted a study of approximately 12,000 students' records from the *National Education Longitudinal Study of 1988* (NELS:88) data and found that among students who were graduated with baccalaureate degrees, those who indicated an interest in a STEM related career while in 8$^{th}$ grade, were two to four times more likely to earn STEM related degrees than those who did not indicate such an interest. Maltese & Tai go so far as to suggest that if our goal is increasing student persistence in STEM, that "teachers should focus on initiating interest and fostering engagement rather than on preparing for standardized examinations" (2010, p. 682) and that policy-makers focus only on achievement and enrollment is misguided (2011, p. 901).

Lindahl (2003), in her 5-year longitudinal study of students in Sweden, also found interest to be of central importance to students; in fact, students listed "interest" as the most important factor for choosing classes in upper secondary school. Lindahl also found that achievement was not as important as one would expect in students' decisions to continue to take STEM coursework. She explains that students, especially girls, mistrusted high course grades; "they seem to feel that to be good they also have to be interested" (p. 10) and that these interests develop early, often in 5$^{th}$ or 6$^{th}$ grade. This highlights the need for students to engage in a variety of STEM activities early in their schooling. This may be essential for encouraging more female students to choose STEM careers, as the majority of women professionals surveyed by Maltese & Tai (2010) cited school-based activities as the origin of their interest in STEM related fields. With the percentage of women preparing for STEM careers on the decline, anything to motivate interest in STEM fields is of great importance.

The smaller number of females in relation to males choosing to pursue careers in STEM fields has been a subject of research for some time (AAUW Educational Foundation, 2000; Ashcraft, et al., 2010; Becker, 2003; Hayes, 2010; Margolis & Fisher, 2002; Misa, 2010). However, *how* women are defined in relation to STEM in this research might be as much of an issue as any lack in interest or skill in these areas for women (Eisenhart, 1996). Jane Abbiss characterizes the past 30 years of research into women and technology as being situated in terms of "male norm and female deficit" (As discussed in Jenson & de Castell, 2010, p. 53). Walkerdine (1994) explains that stories told about women and girls about their "lack" of interest or talent in STEM fields have been used to regulate women and that the endless repetition of these stories is an attempt by dominant cultures to will them to truth. Even what gets recognized as science, technology, engineering, or mathematics is determined by those in positions of power within these fields: historically, upper-middle class white males.

Some have begun to challenge these definitions: bringing into question “all the intellectual tools we have inherited from a male dominated intellectual tradition… including the taken-for-granted world-view of traditional science” (Acker, Barry, & Esseveld, 1991, p. 136), and highlighting the fact that what gets defined as technology, for example, often excludes the “technologies that women use, and/or ‘forget’ women’s contributions to technological innovation” (Jenson & de Castell, 2010). More inclusive definitions of STEM, which incorporate the work’s social significance, will not forget or define away important contributions of women, and may help address deterrents to interest development.

**Deterrents to Engagement and Interest Development**

Deterrents to engagement and interest development in STEM fields, especially for those from underrepresented populations, include working in isolation, seeing the work as lacking social applicability, stereotype threat, and unsupportive learning environments. Keeping social interactions separate from traditional learning and use of science, technology, engineering, or mathematics is artificial and may be one of the reasons that many women and others from underrepresented populations view STEM careers as unwelcoming (Belenky, Clinchy, Goldberger, & Tarule, 2008; Gilligan, 1982; Haraway, 2008). Mies (2008) states, “Social relations are not external to technology but rather [should be] incorporated in the artefacts as such. Such science and technology will therefore not reinforce unequal social relationships but will be such as to make possible greater social justice” (p. 330). This study examines the patterns of collaboration and social relations when learning STEM content and efficacy issues of whether or not one views oneself as able to comfortably function with technological advances.

Stereotype threat (Osborne, 2001; Steele, 1997) can be another deterrent to interest development by having an adverse effect on performance for individuals from populations that have a negative stereotype in a particular domain. The findings regarding stereotype threat hold for women in STEM fields, and racial-ethnic minorities in all academic areas. If individuals have repeated bad experiences in a particular domain, they may begin to de-identify with this domain and this tends to hold firm even if the situation is changed to remove the stereotype threat. So it becomes critical that the initial experiences within a domain where stereotype threat may exist are positive and begin when the student is young.

The classroom learning environment itself may serve to exacerbate the stereotype threat and become another reason that many women and other individuals from underrepresented populations view STEM careers as unwelcoming. Learning environments in many STEM classrooms and extracurricular activities are not welcoming to girls and women and people of color (Becker, 2003; Brickhouse, Eisenhart, & Tonso, 2006; Eisenhart, 1996; Eisenhart & Edwards, 2004; Eisenhart & Finkel, 1998; Hayes, 2010; Margolis & Fisher, 2002; Misa, 2010; Peckham, et al., 2007; Salomone, 2003). As early as elementary school, even when achievement is the same, boys' accomplishments in mathematics are recognized and celebrated, while girls' accomplishments are attributed to hard work rather than intelligence and ability (Campbell, 1995; Corbett, et al., 2008; Walkerdine, 1994). This can send a message to girls early on that they are not able to continue into higher levels of STEM classes. Margolis & Fisher (2002) write, "[T]eachers are critically important for identifying and recruiting girls who would be interested and successful in computer science. But too many teachers and counselors look primarily to boys to have a flair for computing" (p. 48). McDermott's theory of failure can be used to help explain the persistence of these phenomena even in the face of concerted efforts to change definitions of who can excel in STEM fields and to increase women's participation and interest in STEM fields.

Failure is a social construct; by noticing, identifying, and remediating differences, we create categories of those doing well and those who are not. Failure is an integral part of everyone's situations, not just those labeled as failing. McDermott (1987) writes, "we help make failure possible by our presence, by our explanations, and by our successes; similarly, those who fail in school, by their presence, by their being explained, by their failures, make our successes possible" (p. 362). When females are defined as incapable in STEM content, when their successes go unnoticed, when their potential goes untapped, this allows for males to be defined as STEM gifted. Not only are girls not recruited for participation in computer science and other STEM activities and courses, but the learning environments in these spaces can actively discourage girls' interest development in technology and related fields (Hayes, 2010; Misa, 2010).

Changing the environment and teaching methods to include more feminist pedagogies may help to create a classroom climate that is more conducive to learning for women and people of color (Maher & Tetreault, 1994; Rosser, 1989, 2003; Rosser & Kelly, 1994; Rosser & Taylor, 2009). Feminist pedagogies, such as the inclusionary teaching strategies and curricula described by Rosser, encourage teachers to evaluate and modify their instructional practices to reflect the needs and interests of their female and racial-ethnic minority students. For example, girls reported that they liked to make rather than destroy things in computer simulated virtual worlds (AAUW Educational Foundation, 2000), so a computer science unit where students design and create a simulation with opportunities to communicate and collaborate with peers may have broader appeal than one where students individually create a video game based on destroying opponents. A shift in the educational environment to include all students can support the development of strong self-efficacy beliefs and interest in STEM fields for underrepresented students.

**Technology-Enhanced Curriculum to Promote Interest and Self-Efficacy**

Integration of technology in the classroom can engage students in current learning as well as help prepare them for a future that will rely heavily on knowledge and use of technology. Technology in the classroom often includes video games or simulations as a way to excite student interest. Several studies have examined student use of preexisting computer games or simulations to help learn STEM content (Barab, Gresalfi, & Ingram-Goble, 2010; Devlin, 2010; Ke, 2008; Lehrer, Kim, & Schauble, 2007; Lewis, 1998; Sherrell, Francisco, Tran, & Bowen, 2006; Sherrell, Robertson, & Sellers, 2005), while others documented student design of games and simulations (Cherry, Ioannidou, Radar, Brand, & Repenning, 1999; Denner, Werner, Bean, & Campe, 2005; Ioannidou, Repenning, Lewis, Cherry, & Rader, 2003; Kafai & Resnick, 1996; Lee et al., 2011; Repenning, Ioannidou, & Zola, 2000; Werner & Denner, 2005). When students design and create projects from scratch, they become producers, not just users, of technology. Results vary, but include disruption of stereotypes of who can and does use technology, students identifying immediate and applicable use of STEM content, and students (including those traditionally underrepresented in STEM fields) feeling more comfortable and confident with technology.

Shifts in educational environments, as seen in many of the above studies, can support the development of strong self-efficacy beliefs and interest in a particular content area. As self-efficacy is context specific, high self-efficacy in one area does not automatically translate to high self-efficacy in another (Bandura, 1997), students may feel self-efficacious in technology but not in mathematics, or vice versa. This study examines students' self-efficacy and interest development in both mathematics and technology in the context of participation in the technology-enhanced statistics units.

Providing technology-based activities not typically available can create an environment where students can be successful even if they are not often successful in the traditional classroom. In these activities, students are asked to draw on personal experiences and generate creative problem-solving ideas. Often, multiple ways to complete the project are possible, providing many avenues to success. Success can lead to higher self-efficacy beliefs, motivation to repeat the activity, persistence in challenging tasks (Pajares, 2002; Pajares, Hartley, & Valiante, 2001; Usher & Pajares, 2009; Wadsworth, Husman, Duggan, & Pennington, 2007) and possibly lead to the development of long-term interest in the topic. Higher self-efficacy beliefs have also been linked to higher achievement in STEM content (Britner & Pajares, 2001). Student self-efficacy, then, is paramount to developing the ongoing individual interest and achievement needed for future pursuit of a career in a STEM related field.

Since repeated successful experiences can lead to higher self-efficacy, this study compares interest development between students with differing degrees of experience with the AgentSheets software. Some of the students had used the AgentSheets software in some capacity for the last three years; while for others, this was the first exposure. As students gain more experience and programming competence, they may take more ownership in their simulation design and become more engaged in the process. This engagement and competence may translate to increased interest in future experiences using technology and mathematics.

**Engagement**

Marks (2000) provides a working definition of engagement as the "attention, interest, investment, and effort students expend in the work of learning" so that there is both "affective and behavioral participation in the learning experience" (p. 155). The behavioral component is necessary for being able to observe engagement through participation in class activities. In the computer lab engagement is visible by monitoring what students are doing during individual work time and during the teacher presentations. One example of high engagement is student assisting behavior where certain students self-select into "islands of expertise" (Barron, 2010) and offer guidance to others in class. When students assist each other, this can lead to "sparking and sustaining engagement in learning activities" for both the students offering and those receiving help (Barron, 2010, p. 116). Assisting behavior can occur with students close by or even with students in adjacent computer labs. When students move about, the zones of interaction (Shepardson & Britsch, 2006) become obvious. Through analysis of video recordings of classroom interactions, other less obvious zones became apparent. Shepardson & Britsch (2006) discuss how asymmetries in power are linked to asymmetries in 'access'." This study explored if and how student interactions in the computer labs worked to disrupt traditional norms of access and lead to high engagement for a large percentage of students. Furthermore, the type of engagement (Gresalfi & Barab, 2011) was examined overall and by gender subgroups.

Operationalizing engagement to be able to recognize and document when it occurs is essential for studying classroom settings. For example, in the computer lab, when students are collaborating, extending each other's thinking, and sharing excitement over programming a simulation, they are seen as highly engaged in the material. Evidence of disengagement would be behaviors such as surfing the web or other computer activities unrelated to the unit, and of course not using the computer at all (talking to friends, reading a book, doing homework from another class, etc.). Please see Chapter 3 for the specifics of how engagement will be documented during the computer lab classes.

## Theory Informing the Curriculum

Although we are well into the 21st century, the methods of teaching mathematics have remained relatively unchanged. Most classrooms in the United States still rely heavily on teacher-lead lecture style instruction with little input regarding student interests or applicability of the mathematics taught. While this style of teaching works for a minority of students, it is not particularly effective for the majority of students who avoid advanced mathematics and thus eliminate entire career areas from consideration. New models for teaching and learning mathematics can be called upon to help alleviate this issue. Realistic Mathematics Education (van den Heuvel-Panhuizen, 2000, 2001) is one such philosophy.

### Realistic Mathematics Education (RME)

RME is a philosophy of teaching and learning mathematics. It originated from the ideas of Hans Freudenthal (1968) who, when discussing why so many students cannot apply mathematics beyond arithmetic to contexts outside the classroom, writes, "The problem is not what kind of mathematics, but how mathematics has to be taught" (p. 7). He stressed how mathematics is a human activity (Freudenthal, 1971), not just static body of knowledge, emphasizing the social and cultural embeddedness of mathematics as human inquiry into the world around us. In this way, context provides not only a place to apply mathematics but also a place where new mathematical ideas and inquiries are generated.

Freudenthal proposed that students first learn how to apply the mathematics in contexts that they can imagine and use for sense-making and then learn the theoretical mathematics, not the other way around as is often done in formal schooling. Through a process called *horizontal mathematization*, real world situations are symbolized into mathematical expressions. Once in this area of symbolized realities, symbols can be manipulated, shaped, combined, and dissected. Shifting the mathematical reasoning to working with more abstract symbols is called *vertical mathematization*. Historically, mathematics education has focused almost exclusively on formal, symbolic, vertical mathematization. Freudenthal, and others who subscribe to the theories of RME, believe that mathematics education must first focus on reality-based horizontal mathematization to support subsequent vertical mathematization.

The focus on solving problems in context is one of the reasons why RME and statistics education work well together (Bakker, 2004, p. 5). Context is of particular importance when teaching statistics using RME.

### Statistics Education

Beginning in the early 1990's, statistics education has enjoyed a growing interest from policy makers, researchers, and educators (Shaughnessy, 1992, 2007). Many have stated the importance of knowledge of key statistical concepts for an educated citizenry (Kitchen, 1999; Shaughnessy, 2010) and developed lists of 'big ideas' in statistics that are essential for students to learn (Ben-Zvi & Garfield, 2004; Graham, 2006; Lehrer, 2007; Schifter & Fosnot, 1993).

At the middle school level, Bakker (2004) offers his own list, which includes: variability, sampling, data, distribution, and covariation (p. 14). Graham (2006) discusses the need for helping students see connections between the various areas of statistics and data analysis to better allow students to apply new techniques to future situations. Burrill (2005) states that this is often not the case; "students often master technical skills but are unable to use these skills in meaningful ways" (p. 59). How to teach these big ideas in useful and connected ways becomes the challenge. Several models have been developed to try to break down what people *do* when they are solving real world problems using statistical tools. For this project, these models were utilized to develop technology enhanced instructional units for statistics in the middle grades.

Being aware and critical of statistical information, and able to make decisions based on data, are necessary 21st century skills. The philosophy of RME supports the teaching and learning of these skills in meaningful, contextual ways. The use of computer-supported modeling provides access to contexts that could not otherwise be investigated by students.

## Models for Statistical Literacy

### *Statistical Model*

I utilized existing literature on statistics to support the curriculum development during the 2010-2011 school year. Statistical models provided a way to simplify and categorize the areas of statistics we needed to teach to students and the way that we could explain the importance of simulations and statistical tools in data driven decision-making.

Shaughnessy (2007, pp. 964-967) describes models for statistical literacy (Kirsch, Jungeblut, & Mosenthal, 1998) and statistical reasoning (Biggs & Collins, 1982). However, since I wanted a model to describe to students what "real" statisticians do, a 4-dimensional model for statistical thinking by Wild & Pfannkuch (Pfannkuch & Wild, 2002; Wild & Pfannkuch, 1999) proved useful, though too complicated to explain easily to middle school students.  Another model presented by Lappan, Fey, Fitzgerald, Friel & Phillips (2006a, p. 5) provided perspective on meaningful applications of statistics.

Using these two sources as references, I created a Model of Statistical Investigations using Computer Simulations, MSICS, (see Figure 2.2).  This model was presented to students at the beginning of the statistics unit.  It simplifies and captures the process individuals go through when conducting scientific investigations of any type: begin with an authentic question, design a study, include computer simulations as needed, and collect and analyze the data generated to answer the initial question(s).   The teachers I worked with found this representation easy to remember and integrate into classroom teaching.  I expand upon each of the component parts of the MSICS in an example application described after the overview of the Middle Grades Statistics Instructional Sequence used in my research.

**Figure 2.2    Model of Statistical Investigations using Computer Simulations**

***Middle Grades Statistics Instructional Sequence Overview***

With the theory of RME in mind, and with the assistance of classroom teachers, we developed a lesson sequence, including assessment activities, for grades 6-8 in statistics. It addresses the majority of the required standards for grades 6-8 in the statistics strand. Appendix A provides a graphical organization of the instructional sequence. In $6^{th}$ grade, students use measures of central tendency to help make sense of data, while in $7^{th}$ grade students expand their use of graphical representations to include box-plots. In $8^{th}$ grade, students use scatter plots to display and gain information about a sample from a larger population and approximate a line of best fit to make predictions about the population based on this sample.

***Example Application***

The MSICS (Figure 2.2) is presented to students as an introduction to the forest fire simulation unit specifically, and scientific research using statistical data analysis in general. Each of the following sections corresponds to one of the circles in the MSICS.

Context / initial questions. (*Center Circle*).

In accordance with the philosophy of RME, students were provided an imaginable context in which to learn the statistical tools and representations in the learning trajectory. A fictional notice from the Forest Service requires homeowners on wooded lots to reduce the density of the forest surrounding their homes to 50% density. This leads to initial questions, reached with some guidance from the teacher:

- What happens if I don't follow the recommendation?
- Are all forested areas of the state the same? What about those areas damaged by the pine beetle?
- Why 50%? What if I just cut down fewer trees to 60%? Does 10% really matter?

Study design - discussion and planning. *(Top circle).*

Based on the given context, students discussed and planned elements of a study to find answers to the initial questions. Students thought about what tools could be used and considered the ethics of some study designs in this context. For example, they considered: can we burn sections of the forest to test the recommended 50% density level? Can we do this in areas where there are homes? Should we? Teachers guided students to understanding the usefulness of computer simulations in these situations.

Simulation design and creation. (*Right Circle*).

Students designed and created a basic forest fire simulation using the AgentSheets software and concepts of human/computer interaction through abstraction and application of external knowledge as by Cooper, Perez & Rainey (2010). Students considered two properties while designing the forest fire simulation; the density of the forest, and the location of the initial fire.

Data collection. (*Bottom Circle*)

Students then used the simulation they had designed to generate the data needed for the statistical analysis to be done in the unit. Each student ran several cycles of the simulation and, as a class, compiled all student-generated data. This provided opportunities to discuss sampling and why gathering a larger, more representative sample is key to valid results.

Student data analysis – statistics instructional sequence. (*Left circle*).

The statistics content and instruction for $8^{th}$ grade students is within the student data analysis phase of the MSICS. There are 6 main steps, including two assessments of student understanding, in the $8^{th}$ grade portion of the instructional sequence (See Appendix A, Table A.1).

Step 1. *Organizing the data*. Students were provided an Excel worksheet for data collection and organization (See Appendix E).

Step 2. *Interpretation of summary statistics.* Students were asked to complete a reflection section on their excel worksheet.

Step 3. *Graphical representations of data.* Each student plotted his or her data values on a Scatter plots in the excel worksheet.

Step 4. *Interpretation of visual data displays*. The class discussed outliers and the general shape of the data including whether or not the relationships looked linear.

Step 5. *Determining the line of best fit*. Teachers demonstrated how to estimate the line of best fit physically and how to calculate the line using two points. Teachers then asked students to apply their skills to their own data on the excel worksheet.

Step 6. *Using data to make predictions and answer questions*. Students analyzed data to make predictions and answer questions posed for a given context on a posttest (see Appendix C).

The Sim-Stat study examines the implementation of the above curriculum at the middle school level. Classroom activities involving computer-supported modeling and game design were developed and implemented at the middle school level for the last three years as part of the iDREAMS Scalable Game Design project and the Simulations in Statistics study. The next chapter outlines the methods used to collect and analyze students' opinions, experiences, and engagement while participating in these activities.

# Chapter 3. Methods

Battista & Clements (2000) pose the following question that researchers would be wise to answer in the planning phase of the study; "What combination of teaching experiments, classroom observations, interviews, case studies, and paper-and-pencil tests are needed to make sense of what is going on in the classroom against the background of the theoretical analysis that formed the basis for development?" (p. 750). Moreover, what quality of data are needed (Sloane & Kelly, 2008)? Answers to these questions, presented below, not only serve the current study but inform data collection and design activities for my ongoing research in this area.

## Project History

The AgentSheets software had been utilized with students for three years at the middle school where this study was conducted, North Middle School[3]. A Spanish teacher used the software with his students in the 2009-2010 school year. In these classes, students programmed Frogger-type games and learned the associated Spanish words for the nouns and verbs in the game (ex. rana = frog, saltar = to jump). Students did not upload games or complete pre and post-surveys, but this provided exposure and piqued interest for other teachers in the school to participate in the project.

During the 2010-2011 school year, teachers and researchers co-developed and piloted technology-enhanced mathematics units and pre and post content tests that aligned with the district standards and the Colorado Academic Standards (CAS) for statistics and data analysis. These units were placed in an instructional sequence for 6th – 8th grade statistics and probability. Students in 6th grade programmed a Frogger-type game and used a bridge builder

[3] All school, teacher, and student names in this paper are pseudonyms.

simulation to collect data for analysis. Students in 7th grade programmed a Frogger-type game and designed and programmed a virus-spread simulation. Students in 8th grade utilized a preexisting forest fire simulation to collect data to be used in their statistics and data analysis unit.

**2011-12 School Year**

North Middle School was on block schedule for all math classes where students met in math classes daily for approximately 85 minutes. Teachers had 3 blocks daily and a shortened “access” class that serves as the students’ electives period. There were two focus teachers for this study, Ms. Toni Avery and Mr. Rick Connor. All 8th grade students were enrolled in math in one or the other of these teachers’ classes and participated in the statistics curriculum. However, only half of these students were enrolled in classes that used the AgentSheets software to learn statistics during the 2010-11 school year, and of those, a percentage were in Spanish classes using AgentSheets during the 2009-10 school year. This set up interesting comparison possibilities as some students had taken classes using the AgentSheets curriculum for three years, some for two years, and for others this will be the first time they are exposed to the program.

The Sim-Stat unit consisted of 4 days in regular classrooms, 5-6 days in the computer lab, and approximately 3-4 days back in classrooms after the computer lab for additional lessons and post unit testing. Students then returned to the lab approximately one month later and used the AgentSheets software to design and create a Pac-man type game. The post-survey was administered after the second week in the computer lab.

**Participants**

The Sim-Stat study implemented the above curriculum in a rural middle school with a high population of students who qualify for free or reduced cost lunch. The majority of the students in this school were Latino/a, and the primary employers in the community were oil and gas manufacturing companies and local government such as schools and public utilities.

**Teachers:** Four middle school mathematics teachers participated in the iDREAMS project during the 2010-2011 school year at North Middle School: one sixth-grade teacher, one seventh-grade teacher and two eighth-grade teachers. All four had received training in the iDREAMS Summer Institutes in 2010 and 2011 and continued their participation in the 2011-2012 school year. This project focuses on the two 8th grade teachers. The *Computer Simulations in Statistics (Sim-Stat)* units were taught by teachers and supported by researchers, thus researchers were participant observers. Teachers taught related mathematics content as required by their standards and necessary to complete the unit. As a part of their regular classroom assessment practices, teachers administered pre and post mathematics tests, and shared these with researchers for this project.

**Students:** There were approximately 150 middle school students, ages 11-15, recruited for the project. Each of the two 8th grade teachers taught 3 sections of mathematics with approximately 25 students in each class (2 x 3 x 25 = 150). Since all students are required to take mathematics, there were approximately 50% female, and 50% male students. North Middle School had a diverse student body. During the implementation year, according to the school website the student population of NMS was approximately: 60% Hispanic, 37% White, and 3% other race including Native American, Asian, and African American. Of its nearly 600 students, approximately 60% qualified for free and reduced lunch and 40% were classified as ESL students.

## Sim-Stat Implementation Summary

### Unit Preparation

Prior to using the computer lab for the AgentSheets simulation portion of the unit, the students took a pre-test on the statistical content for the next unit. One of the two focus teachers in this study often administered pre-assessments as a method of discovering what prior knowledge students have and to help direct where to focus instruction in the up-coming unit. The other focus teacher practiced this less often, only occasionally utilizing pre-test data. Both teachers then taught lessons from Investigations 2 and 4 in the *Samples and Populations: Data and Statistics* (Lappan, Fey, Fitzgerald, Friel, & Phillips, 2006b), *Connected Mathematics 2* curriculum series. In these lessons, students first considered how to choose a sample from a population to allow one to make predictions or draw conclusions about the entire population. They discussed convenience sampling, systematic sampling, voluntary-response sampling, and random sampling. This section of the unit took 2 class periods.

Over the next two class periods, students learned methods for data analysis when the data contains two related variables. Students were reminded that they used histograms and box plots for analysis and sense-making with univariate data in $6^{th}$ and $7^{th}$ grades respectively. This year students learned that the scatter-plot with a line of best fit were useful data analysis tools for bivariate data. Students also completed practice exercises where they were asked to write the equation of the line of best fit from a graph.

### Computer Lab Set-up

Students from both Ms. Avery's and Mr. Connor's classes went to the computer lab during the same days. There were two adjacent computer labs in North Middle School. Each lab had 30 computers. The lab that Ms. Avery's class was in (Lab 1) had a Promethean board presentation system on a wall near the entrance to the labs. Access to Lab 2 is through Lab 1. The computers in Lab 1 all face toward the left side of the room from the presentation area. The computers in Lab 2 are in a U-shape facing outward from a lectern-style presentation table. See diagrams of each lab in Appendix J. There is no projection set-up in Lab 2. Therefore, the two classes combined in Lab 1 for the unit introduction and all direct instruction portions of the unit.

When they came to the lab, the students chose where they wanted to sit with their partners. Teachers assigned partner-pairs to work on the project. Each student designed and programmed his or her own simulation but their partner was the first person to ask for help with any issue they were having with the project. Only after consulting with his or her partner were students allowed to ask for help from a teacher.

### Simulation Design and Creation (Sim-Stat Unit)

***Day 1. Beginning the Unit.***

On first day in the lab, time was devoted to teaching some basic computer skills such as how to open a browser and where to type in a Uniform Resource Locator (URL). Many students had not been to the computer lab during this school year and there were new student folders for saving work on the network. Step-by-step instructions were provided so that students could access and save to their folders. After this initial computer skills instruction, students spent approximately 15 minutes completing the pre-survey in Survey Monkey.

*Pre-Survey Administration*

Students were asked to complete the pre-survey upon first entering the lab. A *tiny url* was utilized to simplify the address the students needed to type in to the address bar. The first page of the survey was an assent form for participation. If students chose not to participate, the survey ended. All students, whether participating in the research or not, continued to work on the unit with their class and their projects and related coursework be graded as part of the course requirements. Non-participants, however, did not upload their completed projects to the Scalable Game Design Arcade, a repository where student games and simulations were collected. (Students in elementary, middle, and high school, as well as undergraduate and graduate university students have uploaded games and simulations to the arcade.) Non-participants did not complete the post-survey and were not eligible to be selected for interviews. Some students did not return parental consent forms; however, of those with parental consent, no students chose not to participate.

*Unit Introduction*

Students from both classes then moved to the front of Lab 1 and sat on the floor in front of the Promethean board for the introduction of the unit. I introduced the unit using a Prezi (Somlai-Fischer, 2009) presentation[4]. This presentation was developed during the 2010-11 school year as a result of information from a pilot study of a similar unit in 7$^{th}$ grade classes. During the pilot study, the school principal asked students what they were working on in the computer lab had to do with the math they were doing in regular class sessions. Several of the students gave her a blank look, while others offered surface connections such as “we are using numbers” or “we are counting.” The students seemed to have difficulty expressing the

[4] Available at http://scalablegamedesign.cs.colorado.edu/gamewiki/images/5/55/Forest_Fire_Stats_Prezi.zip .

connections between simulation design, creation, and use for data collection with the math they had just completed in the classroom. We decided that a more explicit connection needed to be presented to students to help them verbalize the connections between the sections of the unit. The Prezi presentation used to introduce the teachers to the use of AgentSheets for learning statistics in middle grades was modified and utilized to introduce the Sim-Stat Forest Fire Simulation unit to students.

The Prezi takes students through the various components of answering statistical research questions. Depending on the context and the original questions, the students thought through how they would design a study that could help them answer their questions. The unit presented a context for the students to explore, which is forest fire prevention as it relates to tree density. Because of the vast number of standing dead trees in the mountains of Colorado, and the recent forest fires, this was a current and relevant topic of interest for many.

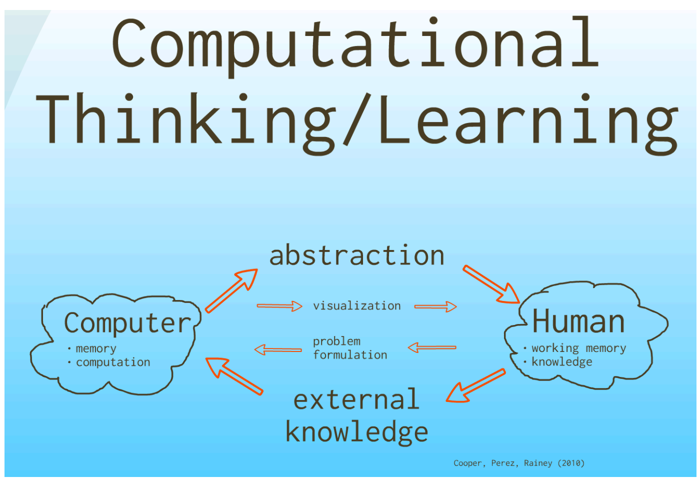
We set the stage by presenting a “recommendation” from the forest service to reduce the density of the trees around any structures to 50% density. We talked about possible first questions that come to mind: Why 50%, not 60%? Because every tree removed increases the cost of time and resources, would 10% or even 20% more trees really matter? What could happen if we don’t follow the recommendation? Is it the same for all areas? Does local wind and humidity conditions make a difference?

We also discussed the limitations of conducting a physical experiment to find answers to these questions. To test if additional tree removal is necessary, it is impossible to re-burn the exact same section of forest twice with different numbers of trees removed, and it may be undesirable or unethical to burn it even once, especially if homes are in the test area. We brought forward other examples when physical experiments are impossible, undesirable, or unethical, like testing global warming theories, virus spread, or avalanche conditions.

Students were asked what other solutions there are to overcome the limitations of physical real-world testing. Students from each class volunteered "computers" or "test it on a computer." We co-defined a working definition of "simulation" and gave examples of simulations they see in everyday living such as a simulation of toothpaste coming out of a tube, or a simulation of local weather conditions.

Then the class explored computational thinking and the relationship between humans and computers. A simplified diagram based on Cooper, Perez, Rainey (2010) was shared with students to show how computer technology allows for humans to visualize and abstract human knowledge to formulate and help solve problems. See Figure 2.3.

**Figure 2.3 Computation Thinking Diagram**




In this specific context, we had to abstract what we know about the spread of a forest fire. If trees are closer together, they have a greater probability of spreading the fire, but this probability is still not equal to one. There is still a chance that a tree will not catch fire even if next to a burning tree. The concepts of probability and density were defined and abstracted in such a way that we could begin to decide how to represent the phenomena as a computer simulation.

I then described how to use our simulations to collect data. The concept of sampling was discussed in relation to the work they did the week before on sampling techniques and criteria. We decided that data from a single run of the simulation would not be considered a representative data sample and that repeated runs of the simulation were necessary. Replicability is one of the main benefits to using a simulation for data collection.

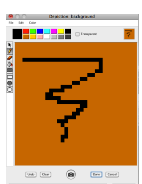
Data analysis was highlighted next and presented as the way to compile, consolidate, and make meaning out of the vast amounts of data collected. We discussed statistical tools like methods for organizing data, finding central tendencies, and representing both univariate and bivariate data graphically. These tools were put in the larger context of the learning line for statistics in middle grades mathematics and beyond. The purpose of using such tools is to be able to answer our questions and make predictions based on the data collected, which often lead to further questions and desired investigations. Thus the cyclical process begins again.

After the Prezi presentation, I demonstrated how to open AgentSheets and begin work on their simulations. As time allowed, students began by creating depictions for the agents (objects) in the simulation such as the background, trees, controller, and starting point for the fire called the *start here* agent. They covered the worksheet with background agents and populated the simulation with healthy trees.

The subsequent days in the computer lab were a blend of supported independent work and direct instruction mini-lessons. During the simulation portion of the unit, I lead the majority of the direct instruction segments following the order of the tutorial so that it could be a resource for students during their independent work time. The tutorial and lesson plan templates were available on the Scalable Game Design (SGD) project wiki[5]. These lesson plans and the tutorial were developed during the pilot study (the 2010-11 school year) and posted to the SGD wiki.

Teachers, a college student (employed by the SGD project to provide implementation support), and I answered individual questions during the students' independent work time. In the beginning of the unit, students primarily sought help from the teachers, the college student, and myself. As the week went on, students began to first turn to each other for assistance and then to the adults if they could not figure it out together.

### *Day 2. Design, Programming, and Testing*

The second day in the lab began with approximately 20 minutes of supported independent work time. The teachers directed the students to the online tutorial and reminded them of what they were to complete. The students were creating agents, which essentially means using drawing tools to create the main components of the simulation. Students finished making depictions of the background, healthy trees, burning trees, and burnt trees. To create the background, the background agents are tiled together to make a solid surface. For example, if the agent looks like this,  the background looks like this:

[5] Tutorial: http://scalablegamedesign.cs.colorado.edu/wiki/Forest_Fire_Tutorial
Lesson plans: http://scalablegamedesign.cs.colorado.edu/wiki/Sample_Forest_Fire_Lesson_Plans)
SGD wiki: http://scalablegamedesign.cs.colorado.edu/wiki/Forest_Fire_Design

Students also made a “start here” agent to be placed on their simulation to have all fires begin near this location. A controller was made as a behind the scenes agent. The tutorial shows the controller as a clock, but the depiction for this agent was not important as it was likely going to be off the screen.

Students then gathered for a 3-minute summary of what they needed to have completed in the next independent work segment. This included creating a new worksheet named “forest fire”, where the simulation would be saved, and using the pencil tool to place ground, healthy tree, start here, and controller agents on the sheet. This presentation was done separately for each class. Lab 1 students stayed in their seats for the direct instruction, but Lab 2 students had to come to the presentation area, as there was no projector set up in their lab. This added transition time to each direct instruction segment.

Students returned to their work for approximately 15 minutes. During this time, if students had large worksheets they were instructed to reduce the overall size so that the simulation would be more user-friendly once uploaded into the Scalable Game Design Arcade. All students were then asked to come to the presentation area for a 7-minute mini-lesson on the next steps to complete the simulation. When the classes merged in the presentation area, the transition took approximately 3-5 minutes. Although this could be considered “lost” instructional time, getting students up and moving occasionally helped to break up the long block classes and gave students a chance to ask quick questions of each other about their progress and process.

In the next direct instruction section, I used the students’ natural pattern of sitting next to each other on the floor to help illustrate how proximity of trees would impact the spread of a forest fire. I asked the class to imagine that they were trees. I chose students sitting in small groups and asked what would happen if a fire was started in this small group. Students answered that all those trees would burn but it would not necessarily spread to other groups. I then selected a larger group of students sitting together and asked what would happen if I started a fire in this group of "trees." We talked about how many more trees would be burned.

We also discussed the chance that a tree has of catching fire even if it is next to a burning tree. Students responded that not all trees catch fire and that there is a chance that the fire would skip a tree. The concept of probability was introduced as our statistical tool to use to simulate this chance. We also talked about the rate of burning. Trees burn at different rates, especially if they are different sizes. I introduced the idea that we could use probability to address this as well. We could tell the computer to assign a chance of changing from a burning to a burnt tree and not have all trees burn at the same rate in our simulation.

After we discussed these ideas conceptually, I showed the students how to use AgentSheets software on the computer to simulate what we understood about forest fires. We assigned an 80% chance of catching fire if next to a burning tree and a 50% chance of a tree changing from burning to burnt in a given simulation cycle. We also discussed how the speed of the computers processing (several hundred cycles per second) actually makes the simulation look unrealistic. Because the computer processes so quickly, and the depictions do not change that quickly, the forest can appear to have trees spontaneously burst into flames. We discussed how to fix this problem by creating two subroutines within the controller agent. First trees must perceive their current status and then they must act on this all together. This makes the simulation more realistic.

Students asked if each of these steps was in the tutorial and they were reassured that they were. Then students returned to their computers to work on programming the "behavior" of the simulation controller. For the remaining 25 minutes of class, students followed the tutorial to program this behavior. During this time, students began to assist one another (mostly those next to them, only a 1-2 students get out of their seats to assist another classmate) with questions as well as asking for help from the teacher. Near the end of the period the teachers guided students through saving work to their H drives and logging out. Two girls stayed on working into lunch. Mr. Connor came over to Lab 1 and he and I helped one girl with debugging the behavior of her simulation controller. Ms. Avery asked them to go to lunch after a bit so she could get ready for next class.

***Day 3. Programming, Testing, and Debugging***

The third day in the lab began with approximately 45 minutes of supported independent work time. The teachers directed the students to the online tutorial and reminded them of what they were to complete.

Students then gathered in the presentation area for approximately 15 minutes of direct instruction. In this lesson I reminded the students of what they were asked to have accomplished by this point in the unit. I asked for a show of hands for how many students were at a point where when they clicked on a tree, the forest fire started and the fire spread. About one-third of the students raised their hands. I asked the students to keep their hands up so that the other students could look around and see who would be a good resource to ask for help in getting to this point.

We then discussed resetting the simulation after an experiment to remove any burnt trees and making sure that the code for the trees was correct. The tutorial had two sequential sections. First the tutorial leads the students to code what many would consider a logical way to program. When programmed this way, the trees seemed to spontaneously burst into flames somewhere away from the main area of the fire. This highlighted the speed of the cycles completed by the computer and how this could lead to a simulation misrepresenting what would occur in a real forest fire. The second part of the tutorial had students remove this section of coding and replace it with the two sub-routines discussed on Day 2 of the unit. If students left both sections of code in the program, the simulation will not work correctly. This is where we began our debugging conversation.

I asked students if they were getting any error messages. Students said that they had messages like "I don't know how to operate on 'ground'", or "I'm just a tree I don't know how to 'perceive'" among others. We discussed the need for the spelling to match the name given to a subroutine and how it is called. For example, if students name the subroutine '*perceive*' and then in another part of the code call to the subroutine named '*persieve*', the computer will not be able to complete the request.

We then moved into the next steps for programming the simulation. I demonstrated how to create a method to generate a new forest by clicking on the controller. This code needed to be placed in the controller behavior. I also showed how to display the simulation properties, which would be needed to collect the data from the simulation for the statistics activities toward the end of the unit. Again I emphasized the need for matching names of properties. Consistent spelling was a common place to look when the simulation was not working as expected.

I then did a live demonstration of the simulation in action. I had a separate simulation for each class and coded it one step at a time so students could see how it developed as they were creating their own simulation. I clicked on tree, clicked on run, and showed the simulation property counters incrementing as the fire spread and the number of burnt trees increased. Students wanted to see the forest regenerate, but I didn't complete this section of code in front of them. At nearly 15 minutes of direct instruction, student attention was wearing thin. Instead, I directed them to the tutorial and did a 1-minute summary of the next three things the students were to work on. They were asked to add the 4 sections of code needed in the controller, to make a new method in the ground to generate a forest, and to set the correct values in the simulation properties.

Students returned to their computers to work independently for the remaining 20 minutes of class. Students were working together with those they were sitting near. Several students began to walk around assisting others (approximately 3-4). As previously mentioned the teachers had assigned partner-pairs to work together and students were asked to sit near their assigned partner. Students seemed to be assisting their friends that they would normally sit with in class. The teachers reminded students to save and log off in the last two minutes of class.

#### ***Day 4. Completion and Teacher Grading***

On the fourth day in the lab, students had supported independent work time for the entire class period in Ms. Avery's class. Mr. Connor provided mini-lessons with no visual (just oral directions). These were fairly ineffective at holding student attention. There is no way in this lab to suspend work on the computers, so students kept working during the directions.

Ms. Avery passed out grading sheets to each of the students. She asked that before they called her over to grade their simulation, that they look over the sheet first and make sure that they had completed all the requirements. This grading rubric is shown in Appendix E. It would have been helpful to have a peer-testing protocol for these students to test each other's simulations. The teachers graded all the simulations and the other adult helpers focused on getting students caught up if they had not yet completed the simulation.

Some students finished early and the teachers allowed these students to play online math skills related games until they could come around and grade their simulations. It was difficult to know if the students who were playing the math games were really done or not.

The class did not upload their simulations to the Scalable Game Design Arcade on Day 4 as was originally planned. The teachers felt that the students needed more time to complete the task. The teachers also did not use the Scalable Game Design arcade as a tool to grade students' assignments outside of class time. When asked, teachers expressed that they were unsure of how to locate all students' simulations in the arcade and did not want to lose student work. They also did not have a shared folder for all student work this year as they had in the past. This year, each student had his or her own folder on the server in which to save work. The teachers would then have to find the simulations in each folder to grade. Both teachers preferred to grade student simulations in class.

***Day 5. Data Collection, Preliminary Data Analysis, and Uploading Simulations***

On the fifth day in the lab, teachers gave students approximately five minutes to get settled, open their AgentSheets simulation, and open the Scalable Game Design Wiki with the tutorial for the forest fire simulation. We then gathered both classes in the presentation area for a ten-minute direct instruction segment. During this lesson, I reminded students that they would need to bring in their signed parental permission slips, if they hadn't done so already in order to upload their simulations to the arcade. I first showed students how to find the Excel spreadsheet they were to use on the server.

I then demonstrated how to use their simulations to collect the data they would need to complete the statistics portion of the unit. I demonstrated changing the density to 50% in simulation properties. I then ran the simulation, showing the simulation properties as they changed while the virtual forest fire spread. I demonstrated how to record the percent burnt value on the Excel worksheet. I then repeated the simulation run for 50% again. I asked students to pretend that I ran the simulation 3 more times and added values for each of the runs for a total of 5 values at 50% density. I then reminded students how to calculate the mean (average) of these numbers.

The students were to use the simulation properties to change the desired forest density. At each density level 10%, 20%, 30%, through 100%, students were asked to run the simulation five times. We discussed how this gave a more representative sample of the "true" percent burnt with a given forest density. We also talked about how our estimate would be even more accurate if we had a larger sample. To keep in the spirit of a scientific experiment, the students were asked to keep all other variables constant, including where the fire was started. The start here agent was a tool used to help ensure approximately equal start locations.

I reiterated the step-by-step directions for how to run their simulation at each density level: reset – change percent density – draw the forest – start the fire – run – record percent burnt. Then I ran the simulation 2 times at 20% density and put in 3 more values for a total of 5 at 20% density. I calculated the mean percent burnt for 20% density and recorded it on the worksheet. I showed students that when they entered the mean percent burnt into the Excel spreadsheet, it automatically plotted the point on the graph.

We also discussed the reflection questions they were asked to complete and how to use the line tool to draw the line of best fit on the Excel worksheet. Students in Mr. Connor's class were asked to email their data collection Excel worksheets and responses to him and cc me. Ms. Avery had students print out their competed Excel worksheets. The students completed these by hand in class if they had not finished in the lab. Ms. Avery checked for completion, but did not collect these worksheets this year.

Students then had approximately 40 minutes of independent work time for data collection and recording. After this, we gathered the students for a short 3-minute direct instruction segment where directions for how to upload a simulation to the Scalable Game Design Arcade were given. Students had been assigned individual logins, but shared a common password. These logins were given to students and they had the approximately 15 minutes remaining in the class period to work independently to upload simulations and continue on data collection and analysis as needed.

***Day 6. Unit Completion and Simulation Uploading.***

Teachers brought students to the computer lab for one day in the following week to take a previously scheduled online math assessment and to wrap up the Sim-Stat unit. Some students had yet to upload their simulations, others had not finished collecting data, or completed the data worksheet. Since all work was on the computer, the teachers wanted to make sure students had access to the lab. Students had approximately half of the class period to work independently on their simulation projects with support from the teacher and the university student.

***Classroom Wrap-up and Post-Testing***

Upon returning to the classroom, the teachers taught follow-up lessons on further data analysis. In particular, the teachers worked with students to draw and calculate the equation for the line of best fit for the data collected from each student's simulation. The students submitted data collection worksheets for grading. After this review, the teachers gave students a post-test where they were asked to apply the statistical tools learned in the unit to novel data sets. These tests were graded and used to inform each student's course grade.

**Computer Game Design and Creation (AgentSheets Unit 2)**

***Day 1. Design, Programming, and Testing.***

Ms. Avery welcomed her class as they were getting settled into the computer lab during the first day of the game design unit. She asked the class to open the Scalable Game Design wiki and locate and open the Pac-man tutorial. Then Mr. Connor's class came into the room and Ms. Avery's class joined them in the presentation area. Mr. Connor presented all direct instruction segments in this unit.

Mr. Connor began by asking the students, "What is Pac-man?" Some of the students gave short summaries of what they knew of the game. Mr. Connor then asked what the objective of the game was. Again students called out answers. Mr. Connor began to redirect the class by letting them know that he would call on them when their hands were up and then when the noise level did not drop he said, "You guys are being disrespectful." When the noise level dropped, Mr. Connor brought a volunteer student up to run the game designed and programmed by Mr. Connor. The game was a Colorado Rockies based Pac-man game. In this game a baseball player agent would move around the game screen "eating" the baseballs and being chased by members of another team. The baseball player could run away, go through tunnels to the other side of the game screen, and throw baseball bats at opponents.

Watching the game being played by their fellow classmate was highly engaging for students. They cheered him on as he beat the first level and advanced to the second level of the game. Mr. Connor was able to talk about the various components of the game as the student played along. It was a good way to introduce the game and demonstrate elements students could incorporate into their own games, such as: user-controlled movement, multiple levels, lives, counters, tunnels, and throwing objects.

Mr. Connor then demonstrated how to get into the Scalable Game Design Arcade. Students were directed to find other games on the arcade to get ideas for how they want to develop their own games and upon returning to their computers in their respective labs, spent 15 minutes exploring the arcade and comparing different versions of Pac-man style games.

Mr. Connor then called the classes back to the presentation area for another directed instruction segment. In this 6-minute segment, Mr. Connor opened by saying that students would really want to pay attention because Pac-man is "more complicated" than the forest fire simulation. Mr. Connor demonstrated how to create a Pac-man agent and use the duplication script feature in AgentSheets to make 4 rotations of the Pac-man agent. To demonstrate the need for this, Mr. Connor acted out being a Pac-man. He walked around the presentation area at first always facing the same direction and showed how this seemed unnatural. Mr. Connor got the students laughing by saying; "It doesn't make sense for Pac-man to be eating pellets with his butt." People (and Pac-man) usually face the direction they are going. When Mr. Connor demonstrated this physically, the students seemed to understand the motivation to create four different depictions of Pac-man facing different directions.

Mr. Connor then discussed wall design. Pac-man games have walls between which the Pac-man and other agents "walk." So that the final design would be visually pleasing, Mr. Connor showed the students how to make a perfectly centered wall agent. He stated, "This takes a little time, but in the end it will pay off because your wall is going to be sexy." The students laughed again and seem focused on what he was demonstrating. Mr. Connor then showed how to make the wall connect well by running another duplication script, this one with full connectivity to get 12 different wall shapes including straight, corners, T's, etc. The majority of the students seemed engaged, offering suggestions and reminders with minimal off-topic talking.

Students returned to their computers for 30 minutes of supported independent work time. Fifteen minutes into this period, Ms. Avery reminded students of the progress they were to have made by this point: Pac-man, wall, and background agents built, and a new worksheet opened ready for agents. Twenty-five minutes into this period, Ms. Avery again reminded students of the progress they were to have made by this point by saying, "You should have a worksheet built with walls in it."

Students were again gathered for a 5-minute segment of direct instruction. In this segment, Mr. Connor demonstrated how to program Pac-man to move around. He asked the students, "What do we have to do to get Pac-man moving around?" Students offer suggestions. Mr. Connor asked how many ways did they need to program Pac-man to move. Together they discussed how it was 4 ways: up, down, right, and left. After Mr. Connor programmed this behavior projected on the Promethean board, he asked "Are we done?" He then showed how to play test the game by saving the behaviors and running the game. It became clear that this was not quite right when the Pac-man agent could walk right through the walls. The students laughed at the sight and Mr. Connor asked them how to solve this problem. They come to the conclusion that Pac-man needs to move only on the ground. One student said, "He needs to *see* the ground", which is one of the commands in AgentSheets. Mr. Connor said, "Who said that?" The student replied, "I did." Mr. Connor said, "You did? [Pause- head nod from student] Good job!"

Mr. Connor then showed the code needed to prevent Pac-man from going through walls and reminded students how to test their games. Mr. Connor demonstrated how to code the Pac-man so he changes direction when he moves. At this point, there was a nice back in forth conversation between Mr. Connor with a few class members. Other students were not paying attention and talking and the noise level was beginning to rise. Mr. Connor dismissed the classes by saying, "Go!" with no summary or review of what students were to do when they got back to their stations. Students were in supported independent work time for the remaining 15 minutes in class.

***Day 2. Design, Programming, and Testing Continued.***

Students spent the first approximately 25 minutes of class working on their game design. Most students were placing background and wall agents on their worksheet to create their game layout. After this period, Mr. Connor invited those who would like some help with the pellets to come to the presentation area. This was an optional direct instruction lesson as some had already programmed their pellets based on the tutorial. Fewer than half of Mr. Connor's and Ms. Avery's students decided to attend the lesson.

In this 3-minute lesson, Mr. Connor went over how to create the pellet agent and program Pac-man to "eat" the pellets. He went over how to add a sound to accompany the pellets being eaten and how to play test. Play testing is to run the game or simulation to see what it does when played. This often highlights malfunctioning aspects of the project to be debugged. Mr. Connor told the students they should get this done and then begin programming the ghost agent by the end of the day. Students had supported independent work time for the remaining class time (about 50 minutes).

***Day 3. Programming, Testing, and Post-Survey Administration.***

On the third day of the Pac-man unit, students came in, got settled, and without prompting opened their games and the wiki tutorial. About 5 minutes into class, Ms. Avery asked students to open Internet Explorer, saying that they had something to "get out of the way" before they got to far into their games. After IE was open for all students, she then pointed to the URL displayed on the Promethean board to go to the online post-survey. She explained that they had taken a similar survey before that was the pre-survey and this was the matching post-survey. The survey took students approximately 7-10 minutes to complete. After finishing the survey, students continued to work on their Pac-man games for the first 25 minutes in class.

Students from both Ms. Avery's and Mr. Connor's classes were then asked to gather in the presentation area for a 10-12 minute direct instruction segment. Mr. Connor asked two student volunteers to play the ghosts and he was the Pac-man. They then acted out the two types of ghost behavior. First he asked the students to move around randomly, then without much effort, he was able to avoid them. Then he asked the students to track him down, saying, "I've got this really nice smelling cologne on and you can smell it to find me." He then started walking, they followed. He went down one row and one ghost followed, the other went down an adjacent row. Within a short time, the ghosts had trapped Pac-man (Mr. Connor), leaving no escape route possible. This scenario was acted out in a similar fashion during the Scalable Game Design Summer Institute, a summer training for teachers implementing SGD units using the AgentSheets software. Mr. Connor was able to directly apply to his classroom lessons learned in the summer institute.

Mr. Connor then directed the students' attention to the board, where his Pac-man was still alive even after letting the game play during this whole demonstration. In all the random movement of the ghosts during this time, they had not come close enough to Pac-man to end the game. He then said, we need to make this game more challenging and have the ghosts track down Pac-man.

Mr. Connor demonstrated how to program the ghosts to track the Pac-man using collaborative diffusion (Repenning, 2006a, 2006b). To ensure accuracy, Mr. Connor encouraged students to copy and paste the diffusion equation rather than typing and retyping as needed. Students originally programmed the ghosts to move randomly (as was done in the original Pac-man arcade game) and were then asked to change to behavior so that the ghosts used artificial intelligence to track Pac-man based on a "scent" trail emitted by Pac-man (as was done in the Ms. Pac-man arcade game). He then emphasized solutions to some of the most common errors and where to look when debugging their games.

In this same direct instruction segment, Mr. Connor showed students other features that were not required, but were extensions for those who were interested in making their games more advanced. This included animation for Pac-man to deflate or spin when he "died." He also said that he would invite students back for an optional lesson on how to make Pac-man "throw stuff." Mr. Connor summarized that students needed to have their ghosts tracking Pac-man by the end of class that day.

Students returned to their computers and worked independently for the approximately 45 minutes remaining in class. Those interested came over to the presentation area to see how to make Pac-man shoot objects. In Mr. Connor's game, the baseball player threw baseball bats at the agents chasing him. The majority of the students stayed at their computers during this short lesson.

***Day 4. Game Completion and Early Uploading to Arcade.***

On the fourth day of the game design unit, the students began with approximately 25 minutes of supported independent work. They then gathered in the presentation area for a 10-minute direct instruction lesson. In this lesson, Mr. Connor explained the “bare minimum” requirements for a “good grade.” However, for this class, which is considered an advanced class, he wanted students to have an end to their games. Mr. Connor showed students how to find directions to program a game end in a different tutorial available on the SGD Wiki for a Sokoban style game. The programming involved broadcasting to the pellet agents and having them respond in order to count the number of remaining pellets. If the number of pellets was zero, then the game ends, displays a message, and resets. If students had more than one level, this would only occur on the last level developed. Students were particularly excited to find out that they got to type in whatever message they wanted the game to display. Customization allowing for individual differences and interests was appealing.

At the end of this presentation, Mr. Connor’s game was not working as expected. We did some on-the-spot debugging and found that there was a spelling mismatch in simulation properties and the controller agent was missing on the worksheet. Many of the students were impatient with this. They asked if they could go back to their computers, while others teased Mr. Connor about his mistakes. I told the classes that they would likely make mistakes as well and that this debugging process is one that is good for them to see, as they would probably be doing something similar. After the new additions to Mr. Connor’s game were working as expected, he demonstrated the new functionality, and then released students to return to their computers.

After approximately 35 minutes of work time, I told the students that they would need to upload their games today if they were not going to be in class tomorrow. Winter break began right after this unit and some students had told their teachers that they would be leaving early for break. I also extended the invitation to upload games to students who were done with their games. The teachers and I began distributing to students their pre-assigned logins. Logins were unique to each individual, but did not personally identify students to others on the Scalable Game Design Arcade. We began helping individual students upload their games as requested, and with about 15 minutes remaining in class I asked a small group of students interested in uploading their games that day to gather around one student's computer and watch as I directed him or her in the steps to upload his or her game to the arcade. These students then returned to their computers and uploaded their games, asking questions as needed.

Students spent the majority of Day 4 in supported independent work. As the work time went on, students spent more time helping each other and would get out of their seats to help someone or ask for help from a student at another computer.

Using AgentSheets, in just 4 days, most students went from a blank screen to a customized, playable, winnable, Pac-man style game. This is a remarkable accomplishment for middle grades students that would be nearly impossible to match with programming languages that have steep learning curves such as C#, Java, or Python.

#### *Day 5. Game Completion, Uploading, and Teacher Grading.*

This was the last day before winter break, and several students were absent. There was a sense of excitement and casualness with both teachers and students relaxing and having some fun. The entire period was supported independent work time. The teachers summarized the things to have accomplished by the end of the class period, as this was the last day in the lab for this unit. When students returned after break, they would not be returning to the lab for any AgentSheets project work.

There were four main items to be completed by the end of the period:

1. Students were to finish their games.
2. There must be a way to win their game and a way to lose their game.
3. Students were to have their projects graded by the teacher (The teacher created grading rubric is in Appendix F.)
4. Students were to upload their games to the Scalable Game Design Arcade

Once students completed these requirements, they tried out each other's games and then were allowed to play math computer games such as *Hooda Math*. About half of the students in each class stayed into their lunch hour working on their projects. Many of these students did not want to submit their games just yet, even though they had met the minimum requirements and the teachers had already graded their projects. Students had modifications and improvements that they wanted to include in their final uploaded version and were working to finish these.

Middle grade students chose to spend their lunch hour in the computer lab for a project for a math class on the last day of school before winter break. This speaks to the high level of engagement from these students. To look more in depth at this engagement, I employed both qualitative and quantitative methods of inquiry. The rest of this chapter summarizes these methods.

**Sources of Data**

This section describes the various sources of data such as interviews, participant observations, and student artifacts that were collected and analyzed in this study. Pre and post motivation survey data, and uploaded student simulations were collected by the iDREAMS project. I had access to this data for this study. The Data Collection Matrix (LeCompte & Schensul, 1999b, p. 138) in Table 3.1 shows the sources of data for each research question. In the section following are detailed descriptions of each of these sources.

**Table 3.1 Project Data Collection Matrix**

| Research Questions | Sources of Data |
|---|---|
| What are students' current levels of interest and self-efficacy in technology and mathematics? | Student Survey, Student Interviews |
| In what ways does interest development differ for students with repeated experiences using the *AgentSheets software*? (i.e. years of participation). | Student Survey, Student Interviews, Field Notes, Videotaped class sessions |
| How does the implementation of technology-enhanced mathematics instructional units affect students' engagement in class discourse and practices? | Field Notes, Videotaped class sessions |
| How does engagement and motivation differ by gender? | Student Survey, Teacher and Student Interviews, Field Notes, Videotaped class sessions |
| What participant positions are available to students in throughout the AgentSheets units? | Field Notes, Videotaped class sessions |
| How do students take up these positions or not? | Field Notes, Videotaped class sessions |

**Artifact-Based Student Interviews**

Just prior to, and during, the implementation of Unit 2, I asked 20 students to participate in artifact-based interviews. See Appendix B for interview protocol. One student declined the invitation to participate, I therefore have 19 recorded student interviews with corresponding student simulations. As described by LeCompte & Schensul (1999b, p. 113), I used Comparable Case Selection to select students who met inclusion criteria. Interview participants were selected based on several criteria: student interest and willingness to participate, teacher recommendation, parental consent granted, and participation in entire Sim-Stat unit through simulation completion. I also ensured that both Ms. Avery's and Mr. Connor's classes were represented and that some students from each class had taken Mr. Samson's class for 7th grade mathematics the previous year.

Selecting some students from Mr. Samson's class served two purposes; first, placement in Mr. Samson's class served as a rough measure of mathematical performance as Mr. Samson taught lower level and remedial courses, and second, students who took Mr. Samson's classes had experience using AgentSheets to create a simulation and were considered part of the "expert" group for use of AgentSheets for this study. The students who used AgentSheets in 6th grade during the 2009-2010 school year (in their Spanish classes) did not have the same saturation of experience as those in later years and in other grades that year. The software was used in a different manner that did not emphasize programming the behaviors and the use of simulations for data collection. For this reason, those who used AgentSheets in 6th and 8th grade, but not 7th grade, and those who used AgentSheets only in 8th grade were included in the AgentSheets Novice group. On the other hand, those who used AgentSheets in 6th, 7th, and 8th grades, or just 7th and 8th grades were included in the AgentSheets Expert group. Table 3.2 depicts these various participation-based groupings.

**Table 3.2 Participation-Based Grouping for Participant Selection**

| | Participation Groups | 6th grade (2009-10) | 7th grade (2010-11) | 8th grade (2011-12) |
|---|---|---|---|---|
| Novice | 1 year of participation (AgentSheets Novice) | No | No | X (Forest Fire Sim) |
| | 2 years of participation (AgentSheets Novice) | X (Spanish) | No | X (Forest Fire Sim) |
| Expert | 2 years of participation (AgentSheets Expert) | No | X (Virus Sim) | X (Forest Fire Sim) |
| | 3 years of participation (AgentSheets Expert) | X (Spanish) | X (Virus Sim) | X (Forest Fire Sim) |

For each interview, I downloaded the student's forest fire simulation from the SGD arcade. Student and interviewer sat side by side in front of a computer and the student walked the interviewer through the depictions in and functionality of their projects. Using their simulation to focus the interview allowed students to be comfortable almost immediately as they were talking about something they had just created. This provided a springboard to questions about interests in STEM courses beyond this class and about likely future pursuits. Students were asked to reflect on satisfaction with their projects, the learning processes needed to complete the project, their experiences during the unit, and their interest in continuing to study STEM fields and pursue STEM careers. Experiences of individuals from populations historically underrepresented in computer science, such as women and people of color, were of most interest to this project. Therefore, a higher percentage of female and Latina/o students were interviewed. Interviews were held at a time convenient for the participant and teacher during independent work time in the classroom and computer lab. All interviews were fully transcribed, coded, and analyzed.

**Participant Observations.**

Participant observations were a main source of data used in this study. During the two weeks of unit implementation, I video and audio recorded class sessions and wrote field notes to help capture the scene in each class. A digital video camera was set up on a tripod in each of the two computer labs and was moved to capture the direct instruction portions of the lesson when students gathered for the next steps in programming. To address sound quality, a shotgun style boom microphone was attached to the main camera. Each teacher and researcher wore a lapel microphone to capture the student/teacher interactions during the independent work time. This resulted in approximately 100 hours of video recordings (2 cameras, 5 hours per day, 10 days) and approximately 200 hours of recorded classroom interactions (3 to 4 microphones, 5 hours per day, 11 days).

For each video recorded class, I created content logs (Jordan & Henderson, 1995), which contained summary statements for every 10 minutes of video. These logs helped me determine which sections of video needed to be coded and/or fully transcribed for analysis. I used NVivo's functionality to allow video and audio to be directly coded without first transcribing into text. Sections of the audio and video recordings were transcribed into text as needed.

**Artifacts.**

Mathematics content tests and worksheets given by the teachers and simulations uploaded by the students to the SGD Arcade were the main artifacts collected, but not examined, in this study. The pre and post content tests (see Appendix C) provided evidence of student thinking around the application of the statistical tools learned in the unit. Students completed data collection worksheets (see Appendix D) in Excel, inputting their data after each run of their simulation. They used this sheet to answer questions, plot data points, physically estimate a line of best fit, and calculate the equation of the line of best fit using two points of the student's choosing. Students from some classes emailed these documents directly to teacher and cc'd me. The other teacher did not collect the worksheets from the students. Students uploaded their completed simulations into an online arcade. I had a list of user name codes and could access students' simulations from the classes in this project. I selected a few representative students and I determined how many completed their simulations, if they were working properly, and if students had added enhancements to the simulations beyond the requirements of the unit.

**Survey Instruments.**

The Student Motivation Survey was developed and validated during the iDREAMS project (Webb & MacGillivary, 2010). A modified version, specific to mathematics classes, was administered online to students prior to the simulation design/statistics units and after they had completed the Pac-man style game design unit. There were three main constructs within the survey: self-efficacy (in math and computers), interest (triggered and maintained), and future pursuits. See Appendix G, Table G.1, for survey questions by construct. The majority of items measuring interest were developed and validated by Linnenbrink-Garcia et al (2010). To evaluate the fit of the constructs stated as being measured by the survey, confirmatory and exploratory factor analysis statistical procedures were applied to he survey. See Factor Analysis Methods section of this chapter.

The surveys included Likert-scale items and open-ended response questions regarding student conceptions of mathematics and computer science, experiences with mathematics and computers, and interest in STEM education. Students were asked to describe their interest in continuing to take computer coursework in the near and more distant future (high school and college) and how difficult or easy they feel computers and math are for them. Students also indicated their gender (male or female), race (students were asked to check all that apply: African American, White, Latino/Latina, Native American, Asian Pacific Islander, or Hispanic), home language (Spanish, English, or other), grade, and age.

## Data Analyses Methods

I primarily used qualitative data analysis methods to address the research questions, though quantitative methods were used for survey validation and analysis. I analyzed the data from interviews, observations, and open-ended items in the surveys using coding schemes and the NVivo program. Both the teachers and myself as a researcher analyzed and scored the content tests and student worksheets.

As detailed above, as a participant observer in the classes I kept field notes and videotaped interactions and participation in the units. Select students were interviewed during the study as well. These data sources were useful in triangulating (Mathison, 1988) findings regarding participation, student engagement, interest development, and understanding of the underlying statistical concepts covered in the unit. Any differences by gender and/or race were of particular interest.

### Analysis phase.

I began analysis early in the data collection period. During the analysis phase, the goal is to make more concise descriptions of the data collected. To do this, Wolcott (2009, p. 29) suggests examining data "using systematic and standardized measures and procedures." LeCompte & Schensul (1999a, p. 3) describe this phase as turning "raw data into 'cooked data' or 'results.'" This step was critical to leading to the interpretative phase.

***Coding procedure.***

*Interview Coding*

I coded the fully transcribed interviews by question, combining and summarizing similar responses. These questions were then grouped by larger construct. For example, responses about self-efficacy in mathematics, self-efficacy in computers, and those addressing a student's previous AgentSheets experience level were grouped and analyzed together. Table 3.3 shows how interview topics were aggregated into larger constructs for analysis.

**Table 3.3 Aggregated Interview Questions by Construct**

| Construct | Related Interview Questions/Topics |
|---|---|
| Self-Efficacy | • Self-efficacy in mathematics<br>• Self-efficacy with computers<br>• Previous AgentSheets experience level as related to gained confidence because of exposure |
| Overall Experience with Sim-Stat Unit | • What was interesting in unit<br>• What was challenging in unit<br>• Favorite and least favorite aspects of unit<br>• What student would do differently if project was repeated<br>• If and how unit made student think differently about uses/capabilities of computers |
| Student Opinion of Using Technology to Learn Mathematics | • Student opinions of collaboration<br>• What student would include in their "own" math class using technology<br>• Value of wiki and tutorial use |
| Interest in Mathematics and Technology | • What learned in general and about statistics<br>• Previous AgentSheets experience level as related to maintained interest |
| Future Pursuits | • Career interests<br>• High school courses students think needed for career interests<br>• Intention to attend college<br>• Any changes in interest in STEM careers |

I also coded the open-ended survey questions. There were three open-ended questions on the post unit survey:

- What do you think about the computer simulation activities?
- How did AgentSheets make you think differently about ways to use computers?
- If you could design a math class that uses computers, what would you like to do?

The open-ended questions were the same as three of the questions asked in the interview. The responses to the survey were from all class members, whereas only 19 students were interviewed. The responses to the open ended survey were included in the analysis and write up for each individual question. Differences, if any, in the overall tone of responses between interviews and the survey were noted by question.

For each of the questions I made several passes through the data. On the first pass, I categorized responses in positive and negative responses to create "big buckets". The big buckets were positive responses (I liked them, I learned from them, etc.) and negative responses (they were too hard, I would not do them again, etc.). On subsequent passes through the student responses, I fine-tuned the categories emerging from the data. The final coding categories for each of the open-ended questions emerged from student responses to the survey.

*Video Coding*

One of the key steps in my analysis was to code each of the sections I determine to be important based on my content logs of videos. For the videos of the computer lab sessions, I looked for what participant positions (M. S. M. O'Connor, 1993) were available to be taken up by students. The initial list of participant positions identified through pilot study data was not exhaustive and through an iterative process of inductive analysis (Patton, 2002) other participant positions were identified and existing definitions were modified. Patton (2002) describes these types of constructed categorical descriptions as "analyst-generated typology" (p. 460).

I coded evidence of students taking up various participant positions:

- Presenting oneself as comfortable & confident with mathematics (CM)
    - Working independently with mathematics (IM)
    - Providing support for others in mathematics (SM)
- Presenting oneself as comfortable & confident with technology (CT)
    - Working independently with technology (IT)
    - Providing support for others in technology (ST)
- Presenting oneself as lacking confidence with mathematics (LM)
- Presenting oneself as lacking confidence or experience with technology (LT)
- Seeking Knowledge (WK)
    - Sharing knowledge with others (SK)
    - Keeping knowledge to self (IK)

These participant positions were not mutually exclusive and were fluid. A student who took up one position could change his participant position on another day or even within the same lesson.

I used the coded behaviors and the participation groups to help identify focal participants. I began by identifying those students within each of the participation groups as shown in Table 3.2. I then identified within each of these groups the participant positions most often taken up by each of the students to help select focal participants. In particular, I identified which categories each focal student was a member of predominantly, and tried to find a representative student in each of the specified categories in Table 3.4. I also selected focal participants based on gender and race so that I would have representation reflective of the school's population. I selected six focal participants; three girls, two Latina and one white, and three boys, two Latino/a and one white. The white male student received special education services.

The participants are listed in Table 3.4. I had focal participants in all but two of the categories. Overall there was a smaller pool of AgentSheets novices than anticipated because of the elective AgentSheets class taught at this middle school by two of the math teachers, Mr. Samson and Mr. Connor. For example, I originally selected Pablo in part because he was an AgentSheets novice, however, this turned out to not be completely accurate. He did not take AgentSheets during his 7th grade year, but he had enrolled in an AgentSheets elective class. Based on this experience, I felt he better represented the AgentSheets Expert, Confident in Math category.

I did not find students at this school lacking confidence in mathematics who were also AgentSheets novices because the students placed in advanced math were the ones who did not use AgentSheets in 7th grade. It was also difficult to find students lacking confidence in technology who were AgentSheets Novices because those confident in math were often also confident in technology. The reverse was not always true, some students were confident in technology but not in math, especially students who were in "lower" math classes in 7th grade.

**Table 3.4 Focal Participant Categories**

| | **Confident with Math (CM)** | **Lacking Confidence with Math (LM)** | **Confident with Technology (CT)** | **Lacking Confidence with Technology (LT)** |
|---|---|---|---|---|
| **AgentSheets Novice (ASN)** | CM with one year of AS experience<br>• Kim (WF) | LM with one year of AS experience | CT with one year of AS experience<br>• Kim (WF) | LT with one year of AS experience |
| **AgentSheets Expert (ASE)** | CM with two or three years of AS experience<br>• Pablo (LM) | LM with two or three years of AS experience<br>• Lia (LF) | CT with two or three years of AS experience<br>• Damian (LM) | LT with two or three years of AS experience<br>• Grace (LF)<br>• Grant (WM) |

After the focal participants were identified, I then wrote vignettes about each of the six students. Vignettes are presented in Chapter 6.

*Inter-Rater Agreement*

To calculate inter-rater agreement for the coding of the video recordings, I asked a fellow mathematics education doctoral student to code some of the video files from the first week of implementation. My colleague applied my codebook to four class periods, coding approximately 6 hours of video recorded classes. She watched and coded four of the five days of the implementation of the Simulations in Statistics unit in one class period in Lab 2. She was directed to pay special attention to the behaviors of one of the students in this class, Lia, who was a focal participant in this study. My colleague recorded her codes on a document with time stamps under each of the video files coded, the code assigned, and a brief description of the observed behavior. This document was then compared to the NVivo coding I completed. I checked each of the codes and descriptions my colleague recorded with how each corresponding section of video was coded in NVivo and my detailed notes for Lia's participation and behaviors.

During this process, I discovered that my colleague had not coded some behaviors all together and had coded other behaviors with two codes. Some of the trouble spots included codes for students waiting for help, keeping information to themselves after receiving help, and classifying out of seat behavior as on or off task. I also used a code for "collaboration" in NVivo that was not in the codebook. This overlapped somewhat with the sharing information code in the information seeking section of the codebook. There was overlap with other codes as well. For example, the code for *wanting and seeking information* under information seeking was too close to the code for *waiting for teacher assistance* under engagement.

These analyses lead to simplification of the codebook. I combined into one code some of the categories that were too similar, and better defined codes. The codebook was updated in the following ways:

- The code for out-of-seat off-task (OS-O) was merged with the off-task code (OT).
- The codes for out-of-seat persisting (OS-P), sharing information (SI), tech support (ST), and math support (SM) were merged into a new code, collaboration (C).
- The code waiting for teacher was re-defined as working with teacher. Any help-seeking behavior now coded into wanting/seeking information (WI).
- The codes for independent work on computer (IT) and independent math work (IM) were merged into the persistence code (P).
- A new code (D) under engagement was added for students who were done with the current task and waiting for the next section of the project.

The codebook was updated to reflect these changes; see Appendix L.

After the codebook was condensed, I updated the codes on the coded videos and applied the new codes to my colleague's list of timestamps and codes. I then calculated the percent of absolute agreement for codes recorded by my colleague for the focal student Lia. I inputted 48 paired codes, which was the number of codes possible for observations (12) multiplied by 4 for the four days of observations. The percent of absolute agreement was approximately 79%. This indicates adequate inter-rater agreement. A rule of thumb is that when using absolute agreement as the measure, 75% or better indicates adequate inter-rater agreement. This method, while simple, does not take into account chance agreement; and since there were only two categories (present or absent) for the 12 codes, chance agreement was likely. To take into account chance agreement, I used SPSS v21 to calculate Cohen's Kappa statistic.

Cohen's Kappa (K) is an index that can be used to measure inter-rater agreement for categorical items. Values of Cohen's Kappa range from -1.0 to +1.0, with -1.0 indicating perfect disagreement below chance, 0.0 indicating agreement equal to chance, and +1.0 indicating perfect agreement above chance. A rule of thumb is that a kappa of .70 or above indicates adequate inter-rater agreement (Morgan, Leech, Gloeckner, & Barrett, 2011), but other sources say that 0.4 or higher is moderate (Landis & Koch, 1977) or fair to good (Fleiss, 1981). The formula for Cohen's Kappa is:

$$K = \frac{\Pr(a) - \Pr(e)}{1 - \Pr(e)}$$

Where Pr(a) = observed percent agreement in coding, and Pr(e) = expected percent agreement by chance if coded in a random manner. Since my colleague and I both observed the same video recordings and coded using the same codebook, these are considered paired observations and we can be compared as raters. Cohen's Kappa was calculated to determine how much our coding agreed while correcting for chance agreement. See Table 3.5.

**Table 3.5 Coder 1 by Coder 2 Crosstabulation and Cohen's Kappa Statistic**

| | | | Coder 2 | | |
|---|---|---|---|---|---|
| | | | 0 | 1 | Total |
| Coder 1 | 0 | Count | 22 | 1 | 23 |
| | | % of Total | 45.8% | 2.1% | 47.9% |
| | 1 | Count | 9 | 16 | 25 |
| | | % of Total | 18.8% | 33.3% | 52.1% |
| Total | | Count | 31 | 17 | 48 |
| | | % of Total | 64.6% | 35.4% | 100.0% |

Measure of Agreement / Kappa = 0.59

Though considered moderate inter-rater agreement, the Kappa statistic results are below the rule of thumb guidelines for high inter-rater agreement. There are several possible reasons for a lower than ideal inter-rater agreement using the codebook developed for the qualitative data in this study.

One of the main reasons for the discrepancies in coding could have been related to access to additional data and familiarity with the study itself. I had a much deeper understanding of what I was seeing in the videos because I had been in the room while they were being recorded. I also was familiar with the activities the students were involved in while being recorded. One example of this causing a difference in coded behavior had to do with the initial 10 minutes of the first video recorded class period. During this time the students were completing the pre-survey. Lia was quietly reading the questions and responding verbally with her answers. I coded her answers as she stated them. At one point, Lia laughed about how she did not understand what was being taught in math class. I coded this as evidence of lower self-efficacy in mathematics. My colleague did not have any codes for this section of the class. This leads me to think that unless one had familiarity with the survey questions and had listened repeatedly to the audio both from the class recordings and the lapel microphones, the significance of these comments might go unnoticed.

Another reason for discrepancies in coding could be related to the interpretation of the codes themselves. My colleague seemed to focus on more overt behaviors and those that were different than what one might consider "normal" behavior for students working in a computer lab. My colleague coded many instances of students raising their hands, getting out of their seats, and off-task behavior. She did not, however, code any instances of persistence (students sitting at their computers completing assigned work) or students receiving help from the teacher. Perhaps only what was different than what might be considered expected behavior seemed worthy of coding. In further research using this codebook, it would be necessary for all coders to come to a shared understanding of what each code meant and what behaviors were to be coded.

**Interpretive phase.**

In contrast to the more "scientific" analysis phase, Wolcott (2009, p. 29) defines the interpretation phase to be one in which the researcher is sense-making, using "intuition, past-experience, [and] emotion – [that are] personal attributes of human researchers." LeCompte & Schensul (1999a) refer to interpretation as "going beyond the results" by "attaching meaning and significance to the patterns, themes and connections that the researcher identified during analysis" (p. 5). My goal in the interpretative phase was to determine to what extent varying participation in AgentSheets units influences students interest development in mathematics and technology applications such as computer simulations.

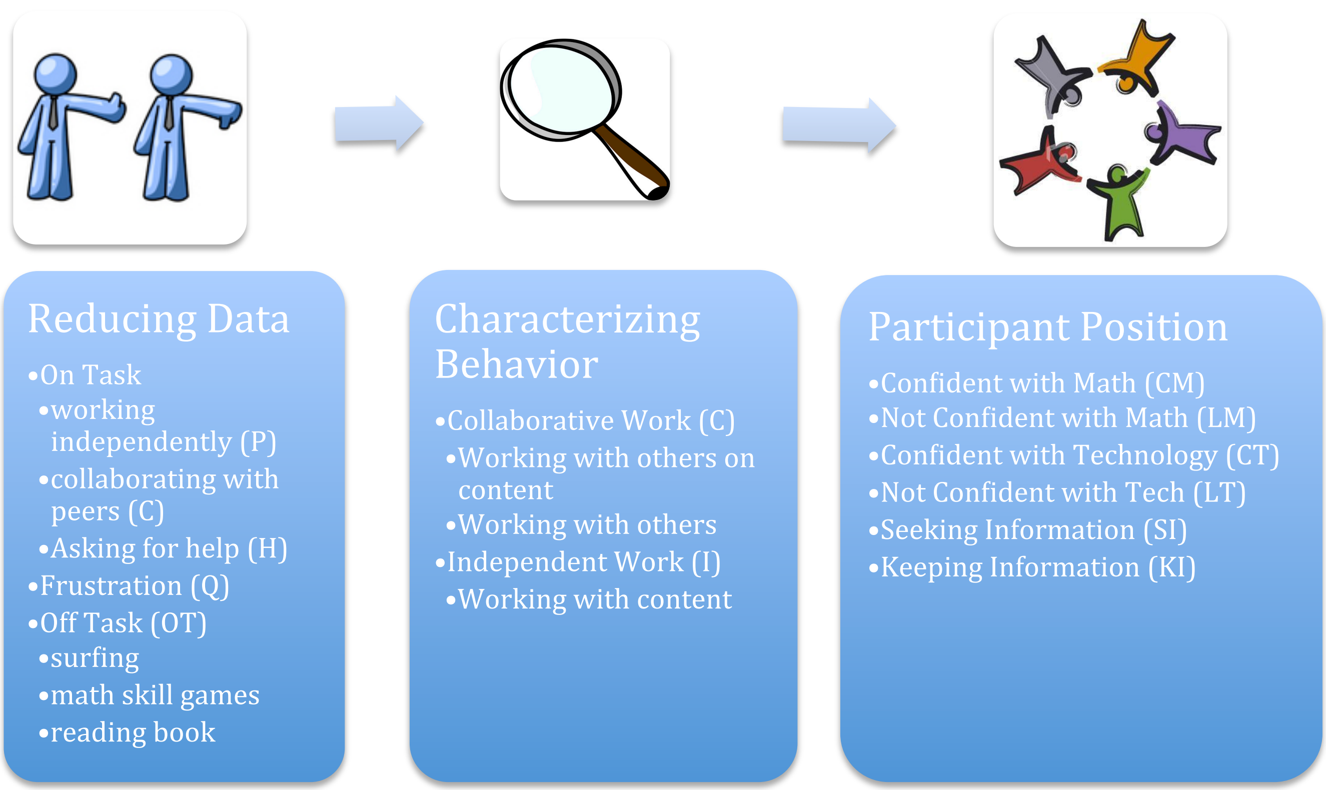
***Analytic Memos***

Analytic memos (Maxwell, 2005) served as a bridge between data collection and analysis. As I collected data, including videos, interviews, and field notes, I wrote memos to begin the analysis and sense making of my observations. I also included analytic memo notes as subsections of my field notes, placing them in italics so that I differentiated between recording of observations and interpretations of these events. I created memos after screening videos, listening to, and/or reading transcriptions of interviews, and examining artifacts. Analytic memos provided a tool for helping me remember and make sense of what I observed, while connecting it to my readings of existing research (Maxwell, 2005) and my pilot study.

***Participant frameworks.***

As a way to examine engagement, I characterized participation much in the way Gresalfi (2009) does in her study of dispositions in mathematics classes. See Figure 3.1 for my initial characterization schema based on Gresalfi's work. Operationalizing participation as observable behavior can provide insight into student engagement. For example, in the computer lab, when I saw students collaborating, extending each other's thinking, and sharing excitement over programming a simulation, I interpreted this as being highly engaged in the material. Evidence of disengagement was behaviors such as surfing the web, doing other computer activities (such as math skill drill programs available on the computer), and of course not being on the computer at all (talking to friends, reading a book, doing homework from another class, etc.).

**Figure 3.1 Participation Characterization Schema**



To document engagement in this study, I used a sketched diagram of both computer labs and put marks next to students' locations at set intervals throughout the class. I placed a P for persistence, C for collaboration between peers, H for receiving teacher assistance, Q for quitting or shutting down, OT for off-task, and D for done with current work. I also annotated with arrows when students were working together with the student next to them or out of their seats assisting/collaborating with other students

- P included working independently on simulation and related activities
- C included peer-to-peer collaboration or assistance on project related tasks
- H was marked when the student was working directly with a teacher, researcher, or undergraduate assistant
- Q was marked when the student was showing signs of frustration but had not moved on to alternate activities (this code was not used frequently in this study and was merged with OT for analysis)
- OT included off-task behaviors such as talking with others about topics unrelated to unit activities, doing other schoolwork, and playing math skill games on the computer without teacher permission.
- D was marked if the student had completed the current portion of the project and was waiting for the class to catch up, for further instruction, or for teacher grading. A note was placed next to students who were given permission by the teacher to play skills-based mathematics computer games because they had completed the simulation and related activities.

When I saw students exhibiting behavior related to P or H, this provided evidence for high engagement. On the other hand, when students were marked Q or OT, I interpreted engagement as low. The amount of effort to reengage students is also related to the mark given. When students are marked OT more intense teacher encouragement was needed to reengage the student. However, when Q is marked, intervention from a teacher at that moment could keep engagement nearly seamless. By characterizing the behaviors exhibited and then calculating the numbers of these events or percent of time on these events, I was able to calculate a more representative measure of how engaged students are in the units over time.

**Cross-case analysis.**

Existing case study research (Stake, 1995, 2010; Yin, 2009) provided useful models for data analysis in this project. I considered each student as a separate but related case. In this way, I did analysis on each individual within a class and then compared the students within and across classes. Cross-case analysis allowed for comparisons between findings for each case. I looked for supporting inferences, as well as those that called into question previous interpretations. Since each class was a different activity system, with different individuals in the class, and a different dynamic with the teacher, cross case analysis helped to expose patterns that seem to hold across activity systems, and expose those that differed between activity systems that appeared similar.

## Subjectivity, Validity, and Reliability

Because this study began as part of an on-going 3-year project, I had worked with these teachers and this curriculum for over 2 years. I helped to develop the units and expand the application of the AgentSheets software into mathematics classes. And yet, I was genuinely interested if and how this program impacted student interest and self-efficacy development in STEM fields over time. I believe in the potential of this approach to affect student engagement and interest development and through an iterative process with teachers feel that we can create a research-based curriculum that works in the classroom.

My long-term involvement with the project introduces researcher bias, but it will also be a benefit by providing rich data. Maxwell (2005) describes how long-term participant observation can provide more in-depth data than many other methods. I understand the program, the curriculum, the math standards the teachers are teaching to, and the district's position on the importance of integrating technology in the content areas. To develop this sort of insight, a researcher must invest much time and have extensive interactions with participants at all levels.

I have supported the meaning I have assigned to interactions with direct quotes from interviews, excerpts from my field notes, and video clips. I looked for disconfirming evidence (Mathison, 1988) and alternate explanations of my interpretations. By triangulating several different sources of evidence, I can better support my conclusions.

**Factor Analysis Methods**

Because I used two previously published surveys, where factor analysis procedures had been used, the factors (constructs) had been previously identified. From the Scalable Game Design Motivation Survey (Webb & MacGillivary, 2010), I used items from three factors: Self-Confidence with Respect to Computer Use (Cronbach's $\alpha = .783$), Future Pursuits (Cronbach's $\alpha = .759$), and Dispositions Toward Computer Class including Simulation-Specific questions (Cronbach's $\alpha = .834$). From the Situational Interest in Academic Domains Instrument (Linnenbrink-Garcia, et al., 2010), I used items from three factors: the Triggered Interest, Maintained Interest due to Feeling, and Maintained Interest due to Value. These constructs are theory-based and were shown to hold together in previous factor analysis. Linnenbrink-Garcia et al (2010) reported fit indices on their Confirmatory Factor Analysis three-factor model of $\chi^2(51) = 113.32$, $p < .001$; CFI = .97, SRMR = .04. Because of the statistical modeling applied to these previously published surveys, Confirmatory Factor Analysis (CFA) was the logical place to start in this study. I ran a CFA, followed by an

Exploratory Factory Analysis (EFA), and then a second CFA based on the findings from the EFA.

**Sample Size Considerations**

The data set used to run all factor analyses was comprised of responses to 27 items on the post-survey from 126 respondents who completed both the pre and post-surveys. This sample size is relatively small for the number of items on the survey. Garson (2008) discusses that Bryant & Yarnold (1995) recommend that the subjects-to-variables (STV) ratio be no less than 5 to 1 and that others such as Gorsuch (1983) and Habing (2003) suggest that the number of subjects be 100 or 5 times the number of items, whichever is greater. More rigorous "rules of thumb" suggest 10 to 15 observations, or more, for each variable (Field, 2009; Lingard & Rowlinson, 2006). If nine more participants would have responded to both the Sim-Stat pre and post-surveys, for a total of 135 matched subjects, the number of respondents would have been five times the number of items. For this survey, the STV ratio is slightly below the 5:1 rule at 4.67.

There were 13 additional respondents who were removed from this analysis because they did either only the pre-survey or the post-survey, but not both. I could have run the analysis on only the pre-survey and would have reached the suggested STV ratio of 5, but decided that I wanted to stay consistent with my analyses and use only the matched pre and post respondents data for all analyses. In either case, 126 or 135 respondents is well below the more demanding rules, which would require approximately 300 to 400 or more respondents for the 27 items on the Sim-Stat Survey.

While some researchers still follow strict rules for sample size, others consider the strength and characteristics of the data itself when determining adequate sample size.

MacCallum, Widaman, Zhang & Hong (1999) write, “the necessary N is in fact highly dependent on several specific aspects of a given study” (p. 86). The authors also discuss the role of communalities. When communalities are high, smaller sample sizes may be adequate for factor analysis. Whereas, when communalities are low, sample size has a greater impact on the quality of solutions from factor analysis procedures. Costello & Osborne (2005) include the size of communalities with other considerations in determining the *strength* of the data. They write, “In general, the stronger the data, the smaller the sample can be for an accurate analysis. ‘Strong data’ in factor analysis means uniformly high communalities without cross loadings, plus several variables loading strongly on each factor” (Costello & Osborne, 2005, p. 4). Communalities are defined as high if all are greater than or equal to 0.8, and low to moderate in the 0.4 to 0.7 range. See Table 3.6 for communalities for this data set for a 4-factor extraction. Small values (yellow) indicate variables that do not fit well with the factor solution, and should possibly be dropped from the analysis. Since only three of the communalities are low (< .30), a small sample size is less likely to distort the results (Leech, Barrett, & Morgan, 2011, p. 70)

**Table 3.6 Communalities for 4-factor EFA**

**Communalities**

| | Initial | Extraction |
|---|---|---|
| #1 SC1 | .640 | .644 |
| #2 SC2 | .657 | .714 |
| #3 SC3 | .594 | .576 |
| #4 TI1 | .631 | .450 |
| #5 MF1 | .629 | .439 |
| #6 FP1 | .418 | .258 |
| #7 FP2 | .609 | .452 |
| #8 FP3 | .674 | .966 |
| #9 SC4 | .533 | .421 |
| #10 TI2 | .553 | .400 |
| #11 SM1 | .715 | .667 |
| #12 TI3 | .413 | .249 |
| #13 MV1 | .715 | .685 |
| #14 MF2 | .710 | .612 |
| #15 SM2 | .764 | .707 |
| #16 MF3 | .752 | .690 |
| #17 SM3 | .838 | .995 |
| #18 TI4 | .701 | .534 |
| #19 MV2 | .691 | .583 |
| #20 SM4 | .654 | .558 |
| #21 MV3 | .675 | .602 |
| #22 TI5 | .602 | .472 |
| #23 FP4 | .575 | .479 |
| #24 MF4 | .851 | .798 |
| #25 MF5 | .782 | .764 |
| #26 SM5 | .457 | .300 |
| #27 MV4 | .683 | .559 |

Extraction Method: Maximum Likelihood.

**Confirmatory Factor Analysis 1**

In this analysis, I first ran a Confirmatory Factor Analysis using the AMOS 17 software program. In AMOS, missing values are problematic. Seventeen of the respondents to the Sim-Stat post-survey had one or more missing values. Because my sample size is relatively small for factor analysis procedures, I decided to impute the missing values rather than delete the cases. I did remove 4 cases where there were more than 2 missing values on the post-survey, but kept the remaining 13 cases with one or two missing values. I do not have the missing-values module in my SPSS package and thus I did not run Little's MCAR test, nor did I use SPSS to impute the missing values with the expectation-maximization (EM) or multiple imputation methods.

SPSS advanced statistics does have missing value replacement by variable functionality. This would have replaced the missing values with the mean of the responses for that variable. This did not seem as logical to me as replacing the values with the mean of each individual's responses. For example, even if an individual had been responding with primarily 1's, the missing value would be replaced by a 3 if that had been the mean for all the other respondents. A better approach seemed to be, if the individual respondent had been marking 4's on average, the missing values would be replaced with a 4 rather than the mean for the item from other respondents. This was possible to do manually as my data set was not too large. Therefore, for each of the 14 cases with one or two missing values, I replaced each missing value with the mean of that respondent's existing responses on other items.

After replacing the missing values, I created and ran the confirmatory factor analysis (CFA). In Appendix H, Diagram H.1 shows the design of the CFA. This diagram also shows standardized estimates for the observed variables, the loadings for each item for the associated construct, and the covariances.

There were high covariances between Triggered Interest and Maintained Interest Feeling (.93) and Maintained Interest Feeling and Maintained Interest Value (.92), which could call to question discriminant validity issues. There were also moderately high covariances between Triggered Interest and both Maintained Interest Value (.84) and Self-Efficacy Math (.85).

There were relatively high loadings for most items (above .70). However, for eight items (numbers 4, 5, 6, 9, 12, 22, 23, and 26), the loadings were relatively low (from .47 to .69), which could explain model fit issues. Table H.1 in Appendix H shows the fit indices for both the theory-based CFA before the EFA was run, and for the CFA based on the results of the EFA.

For the first CFA, AMOS ran 14 iterations to generate the results; indicating that the model was reasonable, though there were some model fit issues. Chi-squared was 607.4 with 309 degrees of freedom, giving a chi-squared to degrees of freedom (reported as CMIN/DF) ratio of 1.966. Tabachnick & Fidell (2008) give a rule of thumb that this ratio should be under 2, which it is, narrowly. The p-value associated with the chi-squared was significant ($p < .001$) which can indicate poor fit of the model to the data (Bryant & Yarnold, 1995).

There are problems with relying exclusively on chi-squared to assess model fit. For example, Tabachnick & Fidell (2008) discuss that with small samples, probability levels can be inaccurate because the computed chi-squared may not be distributed as chi-squared. Therefore, several other fit indices are used to address different aspects of fit. Each of these indices do not look at the same measures of fit, and thus are often used together to develop a more comprehensive picture of model fit. I include 3 model fit indexes in this analysis: GFI, CFI, and RMSEA.

The goodness-of-fit-index (GFI) calculates a weighted proportion of variance through a ratio of the sum of weighted variances from the model covariance matrix to the sum of weighted variances from the sample covariance squared (Peter M. Bentler, 1983; Tabachnick & Fidell, 2008) As a rule of thumb, it is preferable for the GFI to be greater than or equal to .9 (Bryant & Yarnold, 1995). For the first CFA, the GFI was .743. This does not indicate strong model fit.

Bentler's (1990) normed comparative fit index (CFI) compares fit relative to other models by using a noncentral chi-squared distribution and it is preferable for the CFI to be greater than .95 (Tabachnick & Fidell, 2008). It is often the best indicator when working with a small sample. For the first CFA, the CFI was .857. This is not strong support for this model, though this indicates better fit than the chi-squared or the GFI did.

The root mean square error of approximation (RMSEA) developed by Browne & Cudeck (1993) considers the average size of the residuals generated by the model. Values larger than .10 are indicative of a poor fitting model with the preferable range being below .06 for a good-fitting model (Tabachnick & Fidell, 2008). For the first CFA, the RMSEA was .089. Though this did not hit the threshold for a poor model at .1 it was not in the good-fitting model range of below .06.

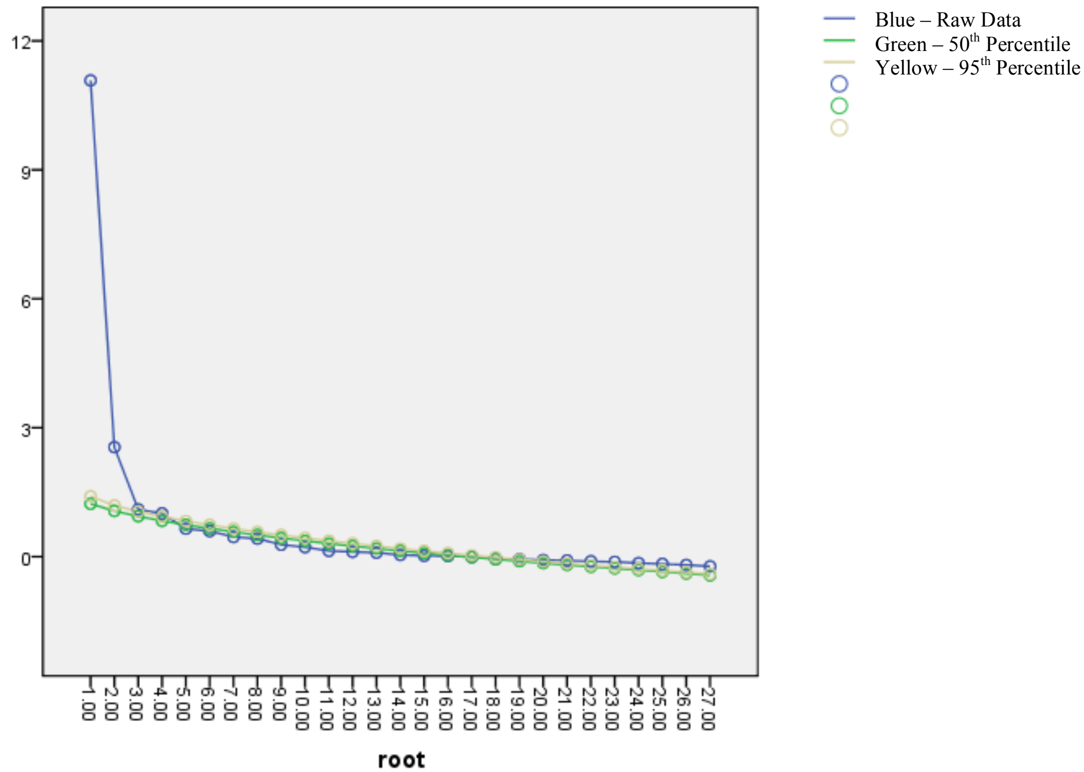
To see if there are items that we could covary to help improve model fit, I looked at the modification indices. I only looked for high covariances between items within the same construct, not between items and the construct, or between items related to different constructs. This is because only items on the same construct can be justifiably covaried. The covariances were high between items 4 and 22 (13.9), items 1 and 2 (12.6) and items 24 and 25 (11.7). Covarying these items did not improve the model fit enough to justify the additional complexity. In the interest of parsimony, I did not covary these items.

Overall, indexes including the chi-squared, the GFI, CFI and RMSEA indicate that while this model is not completely a poor fit for the data, there is room for improvement. Reasons for this could be that the sample size is small, or that the population is different than that used to generate the original analysis of the instruments.

**Exploratory Factor Analysis**

To help determine the number of factors, I ran a parallel analysis (Monte Carlo Analysis of Eigenvalues), examined the scree plot and the eigenvalues (which I did not restrict to larger than 1), and I looked at the variance accounted for by each additional factor. I used SPSS code for the parallel analysis from Brian O'Connor (2000). From this analysis, there were clearly 2 strong factors and 2 factors that were close to, but above, the parallel analysis line. Therefore, 4 factors seemed to be identified. See Figure 3.2.

**Figure 3.2 Parallel Analysis for Post Survey Data**




Examining the eigenvalues also lead to four factors. Notice in Table 3.7 that the Raw Data eigenvalues (the same values SPSS would produce from a principal component analysis) are greater than the 95th Percentile values for the first 4 factors. This identifies statically significant eigenvalues with p at the 0.05 level. Also note the first 4 factors the raw data eigenvalues are above 1, which has historically been used as a cut-off for identifying factors.

Since indicators showed four factors as the number to use, I ran a factor analysis using four factors. I was curious what items would hold together if I used five or six factors, since six factors were originally identified in the instruments used to create the survey. As a result, I ran the exploratory factor analysis for five and six factors as well.

**Table 3.7 Raw Data, 50th Percentile, and 95th Percentile Random Data Eigenvalues**

| Root | Raw Data | 50th Prctyle | 95th Prctyle |
|---|---|---|---|
| 1.000000 | 11.079601 | 1.229378 | 1.401769 |
| 2.000000 | 2.547285 | 1.062274 | 1.189131 |
| 3.000000 | 1.099296 | .939145 | 1.048930 |
| 4.000000 | 1.003960 | .833284 | .930627 |
| 5.000000 | .649795 | .739662 | .827654 |
| 6.000000 | .593532 | .654574 | .738101 |
| 7.000000 | .458715 | .576509 | .652386 |
| 8.000000 | .419137 | .502346 | .574592 |
| 9.000000 | .278121 | .433482 | .502341 |
| 10.000000 | .220676 | .367937 | .433451 |
| 11.000000 | .134507 | .305756 | .369062 |
| 12.000000 | .111938 | .246622 | .307271 |
| 13.000000 | .092678 | .189723 | .245839 |
| 14.000000 | .039800 | .134980 | .187441 |
| 15.000000 | .020358 | .082950 | .132361 |
| 16.000000 | .015359 | .033081 | .080865 |
| 17.000000 | -.002432 | -.015398 | .029582 |
| 18.000000 | -.041828 | -.061808 | -.018561 |
| 19.000000 | -.059124 | -.106770 | -.064956 |
| 20.000000 | -.079436 | -.150488 | -.111266 |
| 21.000000 | -.090488 | -.192529 | -.156774 |
| 22.000000 | -.109400 | -.233579 | -.200435 |
| 23.000000 | -.122500 | -.273413 | -.242190 |
| 24.000000 | -.149898 | -.312292 | -.282083 |
| 25.000000 | -.170888 | -.350882 | -.323884 |
| 26.000000 | -.194080 | -.390787 | -.363022 |
| 27.000000 | -.227376 | -.435886 | -.405447 |

Maximum Likelihood (ML) extraction provides several goodness-of-fit indices not available with other extraction methods. These indices are helpful in determining the number of factors as well as the fit of the model. ML is the preferred method for many (Costello & Osborne, 2005; Fabrigar, Wegener, MacCallum, & Strahan, 1999), but requires the assumption of multivariate normality. While verification of multivariate normality is difficult in SPSS (Leech, et al., 2011), skewness and kurtosis values for the observed variables can be used as a proxy. Analyses using SPSS showed that for the observed variables, the mean of the skewness ranged from .046 to 1.139 with a mean value of .526. All values fell in the acceptable range of ± 2 with all but two in the very good range of ± 1. The absolute value of the kurtosis for this data set ranged from .048 to 1.647 with a mean value of .586. All kurtosis values also fell in the acceptable range of ± 2 with all but four falling in the very good range of ± 1. Thus, the assumption of multivariate normality is not violated as evidenced by these values and the use of the Maximum Likelihood extraction method is not indicated against. Because the assumption of multivariate normality *was* violated in the Linnenbrink-Garcia et al analysis, they used non-normality robust ML (MLM) with robust standard errors and chi-square. MLM is available in Mplus but not in SPSS, therefore, I chose to use maximum likelihood (ML) as it was the most similar to the analysis done by Linnenbrink-Garcia et al.

I also chose to use an oblique rotation allowing for the factors to be correlated. In social sciences, including education, the factors examined are often not expected to be orthogonal. If the constructs are correlated, then oblique rotation generates a better estimate of the factors and a better simple structure. On the other hand even if the factors are uncorrelated, oblique rotation allows for this up to (but not including) 90 degrees and produces results that are nearly identical to orthogonal rotations (Costello & Osborne, 2005). In this way oblique rotation provides the best of both worlds. For my analysis using SPSS, I used the Direct Oblimin oblique rotation with delta = 0.

For all factor analyses, I checked the Kaiser-Meyer-Olkin (KMO) statistic and found they were all greater than .5, which has been used indicate that the data lends itself to factor analysis. I also examined the pattern matrices for 4, 5, and 6 factors.

When 4 factors were extracted, all interest items from the Linnenbrink-Garcia et al (2010) survey loaded on the same factor. See Table I.1 in Appendix I. There was no distinction between triggered and maintained interest, nor between maintained interest for value and feeling. The factors identified could be labeled: Self-Efficacy in Mathematics (SM), Future Pursuits (FP), Interest (I), and Self-Efficacy in Computers (SC).

When 5 factors were asked for, the triggered interest construct became a separate factor. See Table I.2 in Appendix I. However, only two of the triggered interest items were in this factor (items 12 and 18). Furthermore, item 12 had a loading below 0.3 at 0.284, which is considered a low loading by some. The other triggered interest items were in the self-efficacy in computers construct (item 4) and the maintained interest construct (items 10 and 22). As with 4-factor extraction, the maintained interest value and maintained interest feeling loaded on the same factor.

Even when 6 factors were extracted, the maintained interest value and maintained interest feeling items remained together. Extracting more factors did not produce the same factors as theory supporting the instruments used by Webb & MacGillivary and Linnenbrink-Garcia. Also there was not much to be gained in variance accounted for by asking for more factors (4 factors accounted for 57.6% of the variance, 5 factors accounted for 60.1% of the variance – an additional 2.5%, and 6 factors accounted for 62.2% of the variance – an additional 2.1%). Thus, from this point forward, I did all additional analysis on only the 4-factor extraction.

To decide if an item should remain in the analysis, I looked at the MSA (Measure of Sampling Adequacy) on the Anti-Image Correlation Matrix. An MSA value greater than 0.5 can indicate that the item should remain in the factor analysis. For all items in the data set, the MSA was greater than 0.5. Therefore all items were retained for analyses.

**Confirmatory Factor Analysis 2**

I reran a Confirmatory Factor Analysis using the factors suggested by the EFA. I did this for 4 and 5 factors, though only the CFA design and fit indices for 4 factors are show in Appendix H. There were 4 factors suggested by the EFA: Self-Efficacy Math, Interest, Future

Pursuits, and Self-Efficacy Computers. In essence, all constructs related to interest (Triggered Interest, Maintained Interest Feeling and Maintained Interest Value) were placed in one category of *Interest*. Figure H.2, Appendix H, shows the design of the CFA and the standardized estimates for the observed variables, the loadings for each item for the associated construct, and the covariances.

There were moderately high covariances between Self-Efficacy Math and Interest (.79) and between Future Pursuits and Self-Efficacy Computers (.62), which could call to question discriminant validity issues. There were relatively high loadings for many items (above .70). However, nine items: 4, 5, 6, 9, 10, 12, 22, 23, and 26, one-third of the total number of items, had relatively low loadings. Eight of these items were identical to the first CFA, and one new item, number 10, also had low loadings ranging from .41 to .69 in this CFA. Table H.1 in Appendix H shows the fit indices for both the theory-based CFA before the EFA was run, and for the CFA based on the results of the EFA.

For the second CFA, AMOS software also ran 14 iterations to generate the results; indicating that the model was reasonable, though there were some model fit issues. Chi-squared was 587.5 (down by 19.9 from first CFA) with 319 degrees of freedom (up by 9), giving a chi-squared to degrees of freedom (reported as CMIN/DF) ratio of 1.847 (down by .119). This indicates a slightly better fit when using the rule of thumb that this ratio should be under 2. However, the p-value associated with the chi-squared was still significant ($p < .001$), which can indicate poor fit of the model to the data (Bryant & Yarnold, 1995).

I include 3 model fit indexes in the second CFA analysis as well: GFI, CFI, and RMSEA. As a rule of thumb, it is preferable for the GFI to be greater than or equal to .9 (Bryant & Yarnold, 1995). For the second CFA, the GFI was .745 (up by .002). It is preferable for the CFI to be greater than .95 and for the second CFA, the CFI was .871 (up by .014). For the RMSEA, values larger than .10 are indicative of a poor fitting model with the preferable range being below .06 for a good-fitting model. For the second CFA, the RMSEA was .084 (down by .005). Though some indices showed slightly better model fit, these indices still did not indicate a strong fit of the model to the data.

To see if there are items that we could covary to help improve model fit, I looked at the modification indices. I only looked for high covariances between items within the same construct, not between items and the construct, or between items related to different constructs. This is because only items on the same construct can be justifiably covaried. The covariances were high between items 26 and 27 (16.8), items 18 and 19 (17.6), items 11 and 13 (16.9) and items 7 and 16 (11.5). Covarying these items did not improve the model fit enough to justify the additional complexity. In the interest of parsimony, I did not covary these items.

Overall, indexes including the chi-squared, the GFI, CFI and RMSEA indicate that this model provides slightly better fit for the data than the 6-factor model, the difference is not substantial enough to justify changing existing instruments. Possible reasons for poor model-fit in this study could be that the sample size was small, or that although the two populations are described similarly, the population for this study was significantly different in some way as compared to the one used to generate the original analysis of the instruments. Therefore, I will be using the 6 original factors identified by the two instruments used in this project for all subsequent analyses. Results are reported based on the 6 original constructs: Future Pursuits, Self-Efficacy Math, Self-Efficacy Computers, Triggered Interest, Maintained Interest: Feeling, and Maintained Interest: Value. In further research with this instrument, the 4-factor model should be considered as well in analyses.

**Pre-post Survey Analyses**

There were 126 matched respondents across the six sections of 8th grade math. After removing those with multiple missing responses, there were 117 respondents used in the pre-post-survey analysis. These respondents completed both the pre and post-survey and did not have more than two missing items on either survey.

**T-test used to analyze differences in means by factor.**

I ran a paired t-test on each of the six constructs: Future Pursuits, Self-Efficacy in Mathematics, Self-Efficacy in Computers, Triggered Interest, Maintained Interest Feeling and Maintained Interest Value. There were not statistically significant differences in pre-post scores. The results from these calculations are presented in Chapter 4.

**Effect Size Calculations**

Using the mean, standard deviation, and correlation from the t-test calculations, I used and effect size calculator (Cepeda, 2008) to find Cohen's d effect size by construct. The effect sizes were negligible to small using Cohen's (1988) guidelines. The results from these calculations are also presented in Chapter 4.

# Chapter 4. Student Interest and Self-Efficacy in Mathematics and Computers.

## Pre/Post Survey Analyses

To assess students' current levels of interest and self-efficacy in mathematics and computer use, I analyzed the responses provided by students to the pre and post-surveys (Appendix G). The pre-survey was administered on the first day in the computer lab for the Simulations in Statistics (Sim-Stat) unit, and the post-survey was administered near the end of the second unit (game design). There was approximately six weeks between the two survey administrations, which included a weeklong Thanksgiving break for teachers and students. Between the two weeks in the computer lab, students finished up the statistics related activities for the unit for one week, and participated in mathematics lessons unrelated to the Sim-Stat or game design units for two weeks.

To evaluate any differences in means between the pre and post-surveys, I employed a number of statistical methods. I ran both independent and dependent t-tests, calculated effect sizes, and gain scores. The effect size calculations were based on the means and standard deviations for both groups and their related correlation and were calculated using an online effect size calculator (Cepeda, 2008). For areas flagged by the t-tests and effect size calculations as potentially having significantly different means, I ran ANCOVAs and repeated measures mixed ANOVAs. The following section describes the results from all statistical calculations.

### Whole Group Response Analyses

The survey consisted of 43 selected-response questions and 3 open-response questions. The majority of the selected response questions were Likert-style on a 4-point scale from Strongly Disagree to Strongly Agree. On a four-point scale, the midpoint is 2.5. In this survey, therefore, 2.5 denotes the point between disagree response types and agree response types. The means of the student responses for all students on the pre-survey ranged from 2.31 to 3.17 and on the post-survey from 2.30 to 3.13. Means on both surveys were above 2.5 for all but one construct (Future Pursuits).

The highest mean was for responses to questions addressing students' Maintained Interest due to Value (approximately 3.1). Thus, on questions such as, "We are learning valuable things in math class this year" students tended to agree or strongly agree on average. Linnenbrink-Garcia et al (2010) differentiate between finding a subject enjoyable and finding it meaningful and valuable. In this case, regardless of the amount of like or dislike the student felt for mathematics, on average students felt the subject was valuable to them. On average, students also felt confident in their use of computers and with mathematics. Students reported high interest (both triggered and maintained) in mathematics and computer use.

As seen in Table 4.1, the lowest mean was for responses to questions addressing Future Pursuits (approximately 2.3). On questions such as "I would like to study math in college", or "When I get to high school, I want to take computer classes", the mean of students' responses fell below the 2.5 midpoint value on the 4-point scale. Thus the mean of responses would be considered as falling in the disagree half of the scale. On average, students were not interested in pursuing formal STEM activities beyond middle school such as taking computer classes in high school, or studying computers and/or mathematics in college. Students also indicated that, on average, they did not design computer games at home.

There were no significant differences in the means when looking at overall pre-survey results (M = 2.87, SD = .48), as compared with post-survey results (M = 2.86, SD = .51), $t$ (116) = .198, $p$ = .843, $d$ = .019. In fact, for all constructs and subgroups, the 95% confidence interval contained the value zero for all independent or paired t-tests except one. In other words, the difference between the pre-survey and post-survey mean was likely to be between a positive and a negative number, with the possibility that there is no difference at all. The differences, therefore, were not statistically significant in nearly all cases. When considering effect sizes, in whole group comparisons of means by construct, there was a very small effect size (0.14) for the Self-Efficacy with Computers construct. See Table 4.1.

**Table 4.1 Comparison of Pre and Post Survey Responses by Construct (*n* = 117)**

| Variable | | M | SD | Δ Mean | *t* | *df* | *p* | *d* |
|---|---|---|---|---|---|---|---|---|
| Future Pursuits | | | | | | | | |
| | Pre | 2.31 | 0.60 | -0.01 | 0.04 | 116 | 0.97 | 0.00 |
| | Post | 2.30 | 0.67 | | | | | |
| Self-Efficacy with Computers | | | | | | | | |
| | Pre | 2.84 | 0.59 | 0.07 | 1.52 | 116 | 0.13 | 0.14 |
| | Post | 2.91 | 0.64 | | | | | |
| Self-Efficacy with Math | | | | | | | | |
| | Pre | 2.84 | 0.64 | -0.02 | 0.43 | 116 | 0.97 | 0.04 |
| | Post | 2.82 | 0.71 | | | | | |
| Triggered Interest | | | | | | | | |
| | Pre | 3.03 | 0.54 | 0.00 | 0.04 | 116 | 0.67 | 0.00 |
| | Post | 3.03 | 0.55 | | | | | |
| Maintained Interest: Feeling | | | | | | | | |
| | Pre | 2.97 | 0.68 | -0.05 | 0.70 | 116 | 0.49 | 0.06 |
| | Post | 2.92 | 0.66 | | | | | |
| Maintained Interest: Value | | | | | | | | |
| | Pre | 3.17 | 0.58 | -0.04 | 0.76 | 116 | 0.45 | 0.07 |
| | Post | 3.13 | 0.61 | | | | | |
| Overall | Pre | 2.87 | 0.48 | -0.01 | 0.20 | 116 | 0.84 | 0.02 |
| | Post | 2.86 | 0.51 | | | | | |

In summary, only the means of responses to questions on the pre and post-survey addressing the Future Pursuits construct were below the midpoint value. The means of responses to all other constructs and the overall mean for the pre and post-survey were greater than 2.5 on average. Though students liked and felt confident in the subjects of mathematics and technology use, and found value in studying them, fewer students planned on pursuing further formal experiences with them in the future.

**Subgroup Response Analyses**

To see if there were any differences in response patterns by previous experiences levels, gender and/or race, the means of responses by previous AgentSheets experience, gender, and race *between* the pre and post-tests were compared using a dependent-means t-test. A dependent or paired-samples t-test was used in this case because the same matched population took both the pre and the post-survey.

I also compared students' mean responses *within* the pre and post-tests using an independent-means t-test. An independent t-test is applicable here because these are different population samples at the same point in time; e.g. students were required to select male or female as gender. Approximately 60% of the student body was Latino/a and approximately 37% of the population was white. There were very few students (3 of 117 students, 2.5%) who self-identified as any race other than Latino/Latina / Hispanic or White in the survey. Therefore, race was coded as a dichotomous variable due to the population of the classes. By grouping all students together who self-identified as either Latino/Latina or Hispanic I am able to discuss generalizations. We must remain cognizant, however, that within any population self-identifying as the same race there is great variability.

Previous experience with AgentSheets was also coded as a dichotomous variable. Students with two or more years of experience using the AgentSheets software to design and create simulations and computer games were coded as *Expert AgentSheets users* and those with only one year of AgentSheets experience were coded as *Novice AgentSheets users*.

***Previous AgentSheets Experience Comparisons***

The means of the student responses split by previous AgentSheets experience on the post-survey ranged from 2.21 to 3.13, and were above 2.5 for both Novice and Expert AgentSheets users for all but one construct (future pursuits). There were no significant differences in the means when looking at pre-survey results, as compared with post-survey results for either Novice AgentSheets users (pre-survey M = 2.83, SD = .39, post-survey M = 2.81, SD = .45), $t$ (44) = .38, $p$ = .71, $d$ = .06, or Expert AgentSheets users (pre-survey M = 2.89, SD = .54, post-survey M = 2.89, SD = .55), $t$ (71) = .01, $p$ = .99, $d$ = .00 (see Table 4.2). When comparing by level of previous experience using AgentSheets, all effect sizes would be considered smaller than typical at less than 0.3 (see Table 4.2). Though not significant, the largest effect size ($d$ = 0.15) between pre and post-survey was in students' feelings of self-efficacy in computer use. Students reported feeling more self-efficacy and confidence with computer use on the post-survey than on the pre-survey. This held true for both Novice AgentSheets users and Expert AgentSheets users.

**Table 4.2 Subgroup Analyses by Previous Level of Experience using the AgentSheets Program: Paired *t*-test and Effect Size, Overall and by Construct**

| Variable | | | M | SD | Δ Mean | *t* | *df* | *p* | *d* |
|---|---|---|---|---|---|---|---|---|---|
| Future Pursuits | | | | | | | | | |
| | Novice* | Pre | 2.20 | 0.48 | 0.01 | 0.06 | 44 | 0.95 | 0.02 |
| | | Post | 2.21 | 0.65 | | | | | |
| | Expert* | Pre | 2.37 | 0.67 | -0.01 | 0.09 | 71 | 0.93 | 0.02 |
| | | Post | 2.36 | 0.68 | | | | | |
| Self-Efficacy with Computers | | | | | | | | | |
| | Novice | Pre | 2.79 | 0.49 | 0.07 | 0.93 | 44 | 0.36 | 0.15 |
| | | Post | 2.86 | 0.62 | | | | | |
| | Expert | Pre | 2.86 | 0.65 | 0.08 | 1.19 | 71 | 0.24 | 0.15 |
| | | Post | 2.94 | 0.65 | | | | | |
| Self-Efficacy with Math | | | | | | | | | |
| | Novice | Pre | 2.90 | 0.55 | -0.04 | 0.54 | 44 | 0.59 | 0.08 |
| | | Post | 2.86 | 0.60 | | | | | |
| | Expert | Pre | 2.81 | 0.68 | -0.02 | 0.16 | 71 | 0.87 | 0.03 |
| | | Post | 2.79 | 0.78 | | | | | |
| Triggered Interest | | | | | | | | | |
| | Novice | Pre | 3.00 | 0.47 | -0.05 | 0.79 | 44 | 0.44 | 0.11 |
| | | Post | 2.95 | 0.50 | | | | | |
| | Expert | Pre | 3.05 | 0.59 | 0.03 | 0.54 | 71 | 0.59 | 0.06 |
| | | Post | 3.08 | 0.57 | | | | | |
| Maintained Interest: Feeling | | | | | | | | | |
| | Novice | Pre | 2.87 | 0.67 | -0.03 | 0.36 | 44 | 0.72 | 0.05 |
| | | Post | 2.84 | 0.66 | | | | | |
| | Expert | Pre | 3.03 | 0.69 | -0.05 | 0.59 | 71 | 0.56 | 0.07 |
| | | Post | 2.98 | 0.66 | | | | | |
| Maintained Interest: Value | | | | | | | | | |
| | Novice | Pre | 3.17 | 0.49 | -0.05 | 0.74 | 44 | 0.46 | 0.11 |
| | | Post | 3.12 | 0.61 | | | | | |
| | Expert | Pre | 3.16 | 0.64 | -0.03 | 0.45 | 71 | 0.65 | 0.05 |
| | | Post | 3.13 | 0.62 | | | | | |
| Overall | Novice | Pre | 2.83 | 0.39 | -0.02 | 0.38 | 44 | 0.71 | 0.06 |
| | | Post | 2.81 | 0.45 | | | | | |
| | Expert | Pre | 2.89 | 0.54 | 0.00 | 0.01 | 71 | 0.99 | 0.00 |
| | | Post | 2.89 | 0.55 | | | | | |

* Novice N = 45, Expert = 72

The largest differences in means between Novice and Expert AgentSheets users were on the pre-survey on the Future Pursuits and Maintained Interest due to Feeling constructs (Δ Mean = 0.17 and 0.16 respectively), though these differences were not statistically significant. Expert AgentSheets users responded more positively to questions about future coursework and experiences with computers and mathematics and liking and being interested in these subjects. These differences closed somewhat in the post-survey. Overall, the Novice AgentSheets users had a lower mean than the Expert AgentSheets users on both the pre-survey and the post-survey, though this difference was not statistically significant. In fact, there were no statistically significant differences between the mean scores for Expert AgentSheets users and Novice AgentSheets users overall or on any of the sub-constructs when comparing means within the pre-survey and within the post-survey (see Table 4.3).

**Table 4.3 Subgroup Analyses by Previous Level of Experience using the AgentSheets Program: Independent *t*-test, Overall and by Construct**

| Variable | | | M | SD | Δ Mean | *t* | *df* | *p* |
|---|---|---|---|---|---|---|---|---|
| Future Pursuits | | | | | | | | |
| | Pre | Novice* | 2.20 | 0.48 | 0.17 | 1.50 | 115 | 0.14 |
| | | Expert* | 2.37 | 0.67 | | | | |
| | Post | Novice | 2.21 | 0.65 | 0.15 | 1.25 | 115 | 0.21 |
| | | Expert | 2.36 | 0.68 | | | | |
| Self-Efficacy with Computers | | | | | | | | |
| | Pre | Novice | 2.79 | 0.49 | 0.07 | 0.66 | 110.4** | 0.51 |
| | | Expert | 2.86 | 0.65 | | | | |
| | Post | Novice | 2.86 | 0.62 | 0.08 | 0.66 | 115 | 0.51 |
| | | Expert | 2.94 | 0.65 | | | | |
| Self-Efficacy with Math | | | | | | | | |
| | Pre | Novice | 2.90 | 0.55 | -0.09 | 0.80 | 115 | 0.43 |
| | | Expert | 2.81 | 0.68 | | | | |
| | Post | Novice | 2.86 | 0.60 | -0.07 | 0.50 | 115 | 0.62 |
| | | Expert | 2.79 | 0.78 | | | | |
| Triggered Interest | | | | | | | | |
| | Pre | Novice | 3.00 | 0.47 | 0.05 | 0.51 | 115 | 0.61 |
| | | Expert | 3.05 | 0.59 | | | | |
| | Post | Novice | 2.95 | 0.50 | 0.13 | 1.32 | 115 | 0.19 |
| | | Expert | 3.08 | 0.57 | | | | |
| Maintained Interest: Feeling | | | | | | | | |
| | Pre | Novice | 2.87 | 0.67 | 0.16 | 1.21 | 115 | 0.23 |
| | | Expert | 3.03 | 0.69 | | | | |
| | Post | Novice | 2.84 | 0.66 | 0.14 | 1.10 | 115 | 0.27 |
| | | Expert | 2.98 | 0.66 | | | | |
| Maintained Interest: Value | | | | | | | | |
| | Pre | Novice | 3.17 | 0.49 | -0.01 | 0.08 | 115 | 0.94 |
| | | Expert | 3.16 | 0.64 | | | | |
| | Post | Novice | 3.12 | 0.61 | 0.01 | 0.05 | 115 | 0.96 |
| | | Expert | 3.13 | 0.62 | | | | |
| Overall | Pre | Novice | 2.83 | 0.39 | 0.06 | 0.60 | 115 | 0.55 |
| | | Expert | 2.89 | 0.54 | | | | |
| | Post | Novice | 2.81 | 0.45 | 0.08 | 0.77 | 115 | 0.44 |
| | | Expert | 2.89 | 0.55 | | | | |

* Novice N = 45, Expert = 72
** Equal Variances Not Assumed. Levene's test was statistically significant (< .05), so variances between expert and novice on this construct were significantly different and the assumption of equal variance was violated. Therefore, the results from Equal Variances Not Assumed are reported here.

***Gender Comparisons***

The means of the student responses split by gender on the post-survey ranged from 2.30 to 3.19, and were above 2.5 for both male and female students for all but the Future Pursuits construct. There was a statistically significant difference between the pre-survey and post-survey means for female students on the Maintained Interest due to Value construct (see Table 4.4). When comparing pre-survey to post-survey scores for girls on the Maintained Interest due to Value construct, a paired-samples *t* test indicated that there was a statistically significant drop in the mean score (pre-survey M = 3.31, SD = .51, post-survey M = 3.19, SD = .55), $t$ (61) = 2.04, $p = 0.05$, $d = 0.25$. The drop in score was examined further using ANCOVA and repeated measures mixed ANOVA procedures reported below.

Though female students rated their interest in mathematics due to valuing the subject significantly lower on the post-survey than on the pre-survey, the mean for female students responses on the post-survey for this construct (M = 3.19, SD = .55) was still higher than the corresponding mean for male students (M = 3.05, SD = .68). The female-male gap between the mean scores was reduced between the pre and post-surveys. The pre-survey mean score for girls (M = 3.31, SD = .51) on the Maintained Interest due to Value construct was significantly higher than for boys (M = 3.00, SD = .62), $t$ (115) = 2.93, $p = 0.00$. The 95% confidence interval [.1, .5] for this t-test did not contain the value zero. In other words, since the upper and lower bounds for the interval both had the same sign there is a statistically significant difference in these means, though this difference may be as small as .1 on a 4 point scale. This was the only t-test run for this study where the confidence interval did not contain zero.

Overall, male students had a lower mean than female students on both the pre-survey and the post-survey, though these differences were not statistically significant. The only statistically significant differences between male and female students were on the pre-survey for the Maintained Interest due to Value construct described above and on the post-survey for the Triggered Interest construct. On average, girls (M = 3.12, SD = .48) reported significantly higher Triggered Interest than boys (M = 2.93, SD = .60), $t$ (115) = 1.95, $p$ = .05 on the post-survey (see Table 4.5). Girls responded more favorably than boys to statements such as "my math class is often entertaining" and "my math class is so exciting it is easy to pay attention."

When comparing by gender, all effect sizes would be considered smaller than typical at less than 0.3 (see Table 4.4). The largest effect size, other than for the female students on the Maintained Interest due to Value construct ($d$ = .25), was for female students on the Self-Efficacy with Computers construct ($d$ = .16). Girls and boys pre-survey and post-survey scores on Self-Efficacy with Computers were not significantly different, however, there was a larger effect size between girls' pre-survey and post-survey means at $d$ = 0.16, than between boys' pre and post-survey mean scores at $d$ = .11 (see Table 4.4). For both boys and girls, the effect size on the Self-Efficacy with Computers construct had the largest positive effect for all constructs. Both male and female students reported feeling more self-efficacy and confidence with computer use on the post-survey than on the pre-survey with gain scores of 0.08 and 0.06 respectively.

**Table 4.4 Subgroup Analyses by Gender: Paired *t*-test and Effect Size, Overall and by Construct**

| Variable | | | M | SD | Δ Mean | *t* | *df* | *p* | *d* |
|---|---|---|---|---|---|---|---|---|---|
| Future Pursuits | | | | | | | | | |
| | Female* | Pre | 2.29 | 0.67 | 0.02 | 0.25 | 61 | 0.81 | 0.04 |
| | | Post | 2.31 | 0.69 | | | | | |
| | Male* | Pre | 2.32 | 0.55 | -0.02 | 0.23 | 54 | 0.82 | 0.03 |
| | | Post | 2.30 | 0.66 | | | | | |
| Self-Efficacy with Computers | | | | | | | | | |
| | Female | Pre | 2.84 | 0.53 | 0.08 | 1.31 | 61 | 0.20 | 0.16 |
| | | Post | 2.92 | 0.57 | | | | | |
| | Male | Pre | 2.84 | 0.66 | 0.06 | 0.83 | 54 | 0.41 | 0.11 |
| | | Post | 2.90 | 0.71 | | | | | |
| Self-Efficacy with Math | | | | | | | | | |
| | Female | Pre | 2.89 | 0.63 | -0.02 | 0.37 | 61 | 0.72 | 0.04 |
| | | Post | 2.87 | 0.68 | | | | | |
| | Male | Pre | 2.79 | 0.65 | -0.03 | 0.26 | 54 | 0.80 | 0.05 |
| | | Post | 2.76 | 0.75 | | | | | |
| Triggered Interest | | | | | | | | | |
| | Female | Pre | 3.11 | 0.53 | 0.01 | 0.22 | 61 | 0.83 | 0.02 |
| | | Post | 3.12 | 0.48 | | | | | |
| | Male | Pre | 2.95 | 0.55 | -0.02 | 0.29 | 54 | 0.78 | 0.06 |
| | | Post | 2.93 | 0.60 | | | | | |
| Maintained Interest: Feeling | | | | | | | | | |
| | Female | Pre | 3.05 | 0.62 | -0.03 | 0.40 | 61 | 0.69 | 0.05 |
| | | Post | 3.02 | 0.57 | | | | | |
| | Male | Pre | 2.87 | 0.74 | -0.06 | 0.57 | 54 | 0.57 | 0.08 |
| | | Post | 2.81 | 0.74 | | | | | |
| Maintained Interest: Value | | | | | | | | | |
| | Female | Pre | 3.31 | 0.51 | -0.12 | 2.04 | 61 | 0.05 | 0.25 |
| | | Post | 3.19 | 0.55 | | | | | |
| | Male | Pre | 3.00 | 0.62 | 0.05 | 0.61 | 54 | 0.55 | 0.09 |
| | | Post | 3.05 | 0.68 | | | | | |
| Overall | Female | Pre | 2.93 | 0.43 | -0.01 | 0.23 | 61 | 0.82 | 0.02 |
| | | Post | 2.92 | 0.45 | | | | | |
| | Male | Pre | 2.80 | 0.53 | 0.00 | 0.07 | 54 | 0.95 | 0.03 |
| | | Post | 2.80 | 0.57 | | | | | |

* Female N = 62, Male N = 55

**Table 4.5 Subgroup Analyses by Gender: Independent *t*-test, Overall and by Construct**

| Variable | | | M | SD | Δ Mean | *t* | *df* | *p* |
|---|---|---|---|---|---|---|---|---|
| Future Pursuits | | | | | | | | |
| | Pre | Female* | 2.29 | 0.55 | 0.03 | 0.29 | 115 | 0.77 |
| | | Male* | 2.32 | 0.67 | | | | |
| | Post | Female | 2.31 | 0.66 | -0.01 | 0.05 | 115 | 0.96 |
| | | Male | 2.30 | 0.69 | | | | |
| Self-Efficacy with Computers | | | | | | | | |
| | Pre | Female | 2.84 | 0.53 | 0.00 | 0.02 | 115 | 0.98 |
| | | Male | 2.84 | 0.66 | | | | |
| | Post | Female | 2.92 | 0.57 | -0.02 | 0.24 | 115 | 0.81 |
| | | Male | 2.90 | 0.71 | | | | |
| Self-Efficacy with Math | | | | | | | | |
| | Pre | Female | 2.89 | 0.63 | -0.10 | 0.92 | 115 | 0.36 |
| | | Male | 2.79 | 0.65 | | | | |
| | Post | Female | 2.87 | 0.68 | -0.11 | 0.81 | 115 | 0.42 |
| | | Male | 2.76 | 0.75 | | | | |
| Triggered Interest | | | | | | | | |
| | Pre | Female | 3.11 | 0.53 | -0.16 | 1.65 | 115 | 0.10 |
| | | Male | 2.95 | 0.55 | | | | |
| | Post | Female | 3.12 | 0.48 | -0.19 | 1.95 | 115 | 0.05 |
| | | Male | 2.93 | 0.60 | | | | |
| Maintained Interest: Feeling | | | | | | | | |
| | Pre | Female | 3.05 | 0.62 | -0.18 | 1.42 | 115 | 0.16 |
| | | Male | 2.87 | 0.74 | | | | |
| | Post | Female | 3.02 | 0.57 | -0.21 | 1.72 | 115 | 0.09 |
| | | Male | 2.81 | 0.74 | | | | |
| Maintained Interest: Value | | | | | | | | |
| | Pre | Female | 3.31 | 0.51 | -0.31 | 2.93 | 115 | 0.00** |
| | | Male | 3.00 | 0.62 | | | | |
| | Post | Female | 3.19 | 0.55 | -0.13 | 1.11 | 115 | 0.27 |
| | | Male | 3.05 | 0.68 | | | | |
| Overall | Pre | Female | 2.92 | 0.43 | -0.12 | 1.40 | 115 | 0.17 |
| | | Male | 2.80 | 0.53 | | | | |
| | Post | Female | 2.91 | 0.45 | -0.11 | 1.26 | 115 | 0.21 |
| | | Male | 2.80 | 0.57 | | | | |

* Female N = 62, Male N = 55

** Confidence interval does not contain 0.

***Race Comparisons***

At North Middle School, approximately 60% of the students were Latino/a and approximately 37% of the population was white. The pre-survey asked students to identify their race from a provided list containing: Native American, Hispanic, African American, White, Latino/Latina, and Asian Pacific Islander. There were very few students who identified as any race other than Latino/Hispanic or White on the survey; therefore, race was coded as a dichotomous variable. Though this grouping allows for general statements, it does not take into account the variability within each group. It would be wise to further complexify these racial categories by considering other factors such as mother's education level attained and immigration status. These data were not collected in this study, though the survey did ask students to indicate their primary home language. In further examination of these data, taking home language into consideration could begin to highlight variability within the Latino/Latina and Hispanic population in this study.

The means of the student responses split by race on the post-survey ranged from 2.26 to 3.15, and were above 2.5 for both Latino/a and White students for all constructs except the Future Pursuits construct. There were no significant differences in the means when looking at pre-survey results, as compared with post-survey results overall for either Latino/a students (pre-survey M = 2.88, SD = .44, post-survey M = 2.85, SD = .48), $t$ (82) = .92, $p$ = .36, $d$ = .10, or white students (pre-survey M = 2.82, SD = .59, post-survey M = 2.89, SD = .59), $t$ (30) = .66, $p$ = .51, $d$ = .10 (see Table 4.6). When comparing by race, all effect sizes would be considered smaller than typical at less than 0.3 (see Table 4.6). Though not significant, the largest effect size between pre and post-survey was in white students' feelings of self-efficacy in computer use. While both Latino/a and white students reported feeling more self-efficacy and confidence with computer use on the post-survey than on the pre-survey, there was a larger effect size for white students (*d* = 0.25 for white students as compared with *d* = 0.13 for Latino/a students). This construct with the population split by race was examined further using ANCOVA and repeated measures mixed ANOVA procedures reported below.

Between the pre and post-survey, the mean response for Latino/a students dropped overall and in 5 of the 6 constructs, while on these same constructs, the means increased for white students. (See Table 4.6). These differences were not statistically significant, but represent a consistent pattern. The largest drop for Latino/a students was in the Maintained Interest due to Feeling construct (Δ Mean = -.09). However, Latino/a students still had a higher mean (M = 2.93, SD = .62), than white students (M = 2.88, SD = .74) for this construct on the post-survey. The difference was not statistically significantly higher.

**Table 4.6 Subgroup Analyses by Race: Paired *t*-test and Effect Size, Overall and by Construct**

| Variable | | | M | SD | Δ Mean | *t* | *df* | *p* | *d* |
|---|---|---|---|---|---|---|---|---|---|
| Future Pursuits | | | | | | | | | |
| | Latino* | Pre | 2.29 | 0.58 | -0.03 | 0.37 | 82 | 0.71 | 0.05 |
| | | Post | 2.26 | 0.67 | | | | | |
| | White* | Pre | 2.37 | 0.70 | 0.04 | 0.36 | 30 | 0.73 | 0.07 |
| | | Post | 2.41 | 0.71 | | | | | |
| Self-Efficacy with Computers | | | | | | | | | |
| | Latino | Pre | 2.82 | 0.49 | 0.07 | 1.10 | 82 | 0.28 | 0.13 |
| | | Post | 2.89 | 0.55 | | | | | |
| | White | Pre | 2.88 | 0.82 | 0.10 | 1.31 | 30 | 0.20 | 0.25 |
| | | Post | 2.98 | 0.86 | | | | | |
| Self-Efficacy with Math | | | | | | | | | |
| | Latino | Pre | 2.81 | 0.63 | -0.06 | 1.30 | 82 | 0.20 | 0.16 |
| | | Post | 2.75 | 0.70 | | | | | |
| | White | Pre | 2.88 | 0.67 | 0.09 | 0.73 | 30 | 0.47 | 0.13 |
| | | Post | 2.97 | 0.74 | | | | | |
| Triggered Interest | | | | | | | | | |
| | Latino | Pre | 3.07 | 0.50 | -0.02 | 0.63 | 82 | 0.53 | 0.08 |
| | | Post | 3.05 | 0.52 | | | | | |
| | White | Pre | 2.91 | 0.63 | 0.07 | 0.59 | 30 | 0.56 | 0.11 |
| | | Post | 2.98 | 0.60 | | | | | |
| Maintained Interest: Feeling | | | | | | | | | |
| | Latino | Pre | 3.02 | 0.62 | -0.09 | 1.31 | 82 | 0.20 | 0.13 |
| | | Post | 2.93 | 0.62 | | | | | |
| | White | Pre | 2.81 | 0.81 | 0.07 | 0.43 | 30 | 0.67 | 0.08 |
| | | Post | 2.88 | 0.74 | | | | | |
| Maintained Interest: Value | | | | | | | | | |
| | Latino | Pre | 3.21 | 0.51 | -0.06 | 1.31 | 82 | 0.20 | 0.14 |
| | | Post | 3.15 | 0.52 | | | | | |
| | White | Pre | 3.02 | 0.73 | 0.04 | 0.26 | 30 | 0.80 | 0.05 |
| | | Post | 3.06 | 0.79 | | | | | |
| Overall | Latino | Pre | 2.88 | 0.44 | -0.03 | 0.92 | 82 | 0.36 | 0.08 |
| | | Post | 2.85 | 0.48 | | | | | |
| | White | Pre | 2.82 | 0.59 | 0.07 | 0.66 | 30 | 0.51 | 0.12 |
| | | Post | 2.89 | 0.59 | | | | | |

* Latino/a N = 83, White N = 31

The largest differences in means between Latino/a and white students were on the pre-survey on the Maintained Interest due to Feeling and Maintained Interest due to Value constructs ($\Delta$ Mean = 0.21 and 0.19 respectively) and on the post-survey on the Self-Efficacy with Mathematics construct ($\Delta$ Mean = 0.22). See Table 4.7. Though these differences were not statistically significant, Latino/a students had a higher mean response than white students for statements such as "I enjoy the work I do in this class" and "what we are studying in math class is useful for me to know", while white students had a higher mean response to statements such as "doing math is easy for me" and "I am confident in my ability to solve math problems." On average, however, both Latino/a and white students agreed with these and other related statements.

There were no statistically significant differences between the mean scores for Latino/a students and white students on any of the constructs when comparing means within the pre-survey and within the post-survey (see Table 4.7). This lends support to Claim 2: "Students social addresses are not good indicators of their … interest level … in the Simulations in Statistics activities."

**Table 4.7 Subgroup Analyses by Race: Independent *t*-test, Overall and by Construct**

| Variable | | | M | SD | Δ Mean | *t* | *df* | *p* |
|---|---|---|---|---|---|---|---|---|
| Future Pursuits | | | | | | | | |
| | Pre | Latino* | 2.29 | 0.58 | 0.08 | 0.66 | 112 | 0.51 |
| | | White* | 2.37 | 0.70 | | | | |
| | Post | Latino | 2.26 | 0.67 | 0.16 | 1.10 | 112 | 0.27 |
| | | White | 2.42 | 0.71 | | | | |
| Self-Efficacy with Computers | | | | | | | | |
| | Pre | Latino | 2.82 | 0.49 | 0.06 | 0.36 | 38.4** | 0.72 |
| | | White | 2.88 | 0.82 | | | | |
| | Post | Latino | 2.89 | 0.55 | 0.09 | 0.58 | 39.6** | 0.57 |
| | | White | 2.98 | 0.85 | | | | |
| Self-Efficacy with Math | | | | | | | | |
| | Pre | Latino | 2.81 | 0.63 | 0.07 | 0.48 | 112 | 0.63 |
| | | White | 2.88 | 0.67 | | | | |
| | Post | Latino | 2.75 | 0.70 | 0.22 | 1.52 | 112 | 0.13 |
| | | White | 2.97 | 0.74 | | | | |
| Triggered Interest | | | | | | | | |
| | Pre | Latino | 3.07 | 0.50 | -0.16 | 1.46 | 112 | 0.15 |
| | | White | 2.91 | 0.63 | | | | |
| | Post | Latino | 3.05 | 0.52 | -0.07 | 0.59 | 112 | 0.56 |
| | | White | 2.98 | 0.60 | | | | |
| Maintained Interest: Feeling | | | | | | | | |
| | Pre | Latino | 3.02 | 0.62 | -0.21 | 1.44 | 112 | 0.15 |
| | | White | 2.81 | 0.81 | | | | |
| | Post | Latino | 2.93 | 0.62 | -0.05 | 0.40 | 112 | 0.69 |
| | | White | 2.88 | 0.74 | | | | |
| Maintained Interest: Value | | | | | | | | |
| | Pre | Latino | 3.21 | 0.51 | -0.19 | 1.58 | 112 | 0.12 |
| | | White | 3.02 | 0.73 | | | | |
| | Post | Latino | 3.15 | 0.52 | -0.09 | 0.58 | 40.2** | 0.57 |
| | | White | 3.06 | 0.79 | | | | |
| Overall | | | | | | | | |
| | Pre | Latino | 2.88 | 0.44 | -0.06 | 0.63 | 112 | 0.53 |
| | | White | 2.82 | 0.59 | | | | |
| | Post | Latino | 2.85 | 0.48 | 0.04 | 0.40 | 112 | 0.69 |
| | | White | 2.89 | 0.59 | | | | |

* Latino/a N = 83, White N = 31

** Equal Variances Not Assumed

**Further Analyses**

***Analysis of Covariance***

Constructs flagged as significantly different for gender and race by *t* tests and effect sizes were further examined using analysis of covariance (ANCOVA) and repeated measures mixed analysis of variance (ANOVA) statistical procedures. One construct by gender and one construct by race were flagged. Therefore, two ANCOVAs / mixed ANOVAs were calculated controlling for pre-survey scores. First, independent *t* tests indicated that there were significant differences by gender on the Maintained Interest due to Value construct on the pre-survey so this construct by gender warranted a closer look. Second, although not statistically significant, there was a larger effect size for the Self-Efficacy with Computers construct for white students than for Latino/a students, so further analysis seemed warranted to examine these differences.

An ANCOVA was used to assess whether female students had a higher post-survey mean on the Maintained Interest due to Value construct than male students after controlling for differences in mean pre-survey responses (see Table 4.9). Another ANCOVA procedure was used to assess whether white students had higher post-survey mean scores on the Self-Efficacy with Computers construct than Latino/a students when controlling for differences in pre-survey responses (see Table 4.11).

The ANCOVA procedure takes into account other variables that influence the outcome, creating equal starting points for respondents and then comparing means. Use of ANCOVA allows us to reduce the within group variance and more accurately assess the effect of the independent variable (Field, 2009). In this case, the influence of the pre-survey score on the post-survey score is accounted for so that we can assess the impact of gender or race on the score assuming equal pre-survey means.

The following assumptions for each ANCOVA were checked: independence (scores on the dependent variable were independent of each other), normality (distributions within the dependent variables were normally distributed – See Appendix K), linear relationships between the covariate (pre-survey scores) and the dependent variable (post-survey scores), homogeneity of regression slopes (the factor and covariate did not interact), and homogeneity of variance (the samples have similar variances). All assumptions were met for the ANCOVA used to assess whether female students had a higher post-survey mean on the Maintained Interest due to Value construct than male students after controlling for differences in mean pre-survey responses. For the ANCOVA used to assess whether white students had higher post-survey mean scores on the Self-Efficacy with Computers construct than Latino/a students when controlling for differences in pre-survey responses, the assumption of homogeneity of regression slopes was violated ($p = .01$). Because there was interaction between the slopes of the factor (race) and the covariate (pre-survey scores), the conclusions drawn from this ANCOVA could be questioned. All other assumptions were met.

For the ANCOVA used to assess whether female students had a higher post-survey mean on the Maintained Interest due to Value construct than male students after controlling for differences in mean pre-survey responses, results indicate that there is not a significant difference between female and male students' post-survey mean scores for the Maintained Interest due to Value construct, $F(1, 114) = .23$, $p = .64$, partial $eta^2 = .27$ when controlling for pre-survey scores. See Table 4.8 for the means and standard deviations for female and male students on the Maintained Interest due to Value construct before and after controlling for pre-survey scores. On the post-survey, the differences between the means for females and males were not statistically significant before and after the ANCOVA. Though the girls' unadjusted means were slightly higher than the boys' unadjusted means, this reversed once the pre-survey scores were controlled for. The girls' adjusted means were slightly lower than the boys' adjusted means (see Table 4.8).

**Table 4.8 Adjusted and Unadjusted Gender Means and Variability for Post-Survey Scores on the Maintained Interest due to Value Construct Using Pre-Survey Scores as a Covariate**

| | | Unadjusted | | Adjusted | |
|---|---|---|---|---|---|
| | N | M | SD | M | SE |
| Females | 62 | 3.19 | 0.68 | 3.10 | 0.07 |
| Males | 55 | 3.06 | 0.55 | 3.15 | 0.07 |

**Table 4.9 Analysis of Covariance for Post-Survey Scores on the Maintained Interest due to Value Construct as a Function of Gender Using Pre-Survey Scores as a Covariate**

| Source | *df* | *Mean Sq.* | *F* | *p* | $eta^2$ |
|---|---|---|---|---|---|
| Pre-Survey | 1 | 11.83 | 43.13 | 0.00 | 0.27 |
| Gender | 1 | 0.06 | 0.23 | 0.64 | 0.00 |
| Error | 114 | 0.27 | | | |

In summary, though there were significant differences between boys and girls mean scores on the Maintained Interest due to Value construct on the pre-survey, these differences were not significant on the post-survey whether or not one controlled for the pre-survey score using an ANCOVA procedure.

For the ANCOVA used to assess whether white students had higher post-survey mean scores on the Self-Efficacy with Computers construct than Latino/a students when controlling for differences in pre-survey responses, results indicate that there was not a significant difference between Latino/a and white students' post-survey mean scores for the Self-Efficacy with Computers construct, $F(1, 111) = .28$, $p = .60$, partial $eta^2 = .42$. See Table 4.10 for the means and standard deviations for Latino/a and white students on the Self-Efficacy with Computers construct before and after controlling for pre-survey scores.

**Table 4.10 Adjusted and Unadjusted Race Means and Variability for Post-Survey Scores on the Self-Efficacy with Computers Construct Using Pre-Survey Scores as a Covariate**

| | | Unadjusted | | Adjusted | |
|---|---|---|---|---|---|
| | N | M | SD | M | SE |
| Latino/Multi | 83 | 2.89 | 0.55 | 2.90 | 0.05 |
| White | 31 | 2.98 | 0.86 | 2.96 | 0.09 |

**Table 4.11 Analysis of Covariance for Post-Survey Scores on the Self-Efficacy with Computers Construct as a Function of Race, Using Pre-Survey Scores as a Covariate**

| Source | *df* | *Mean Sq.* | *F* | *p* | $eta^2$ |
|---|---|---|---|---|---|
| Pre-Survey | 1 | 19.75 | 80.40 | 0.00 | 0.42 |
| Race | 1 | 0.07 | 0.28 | 0.60 | 0.00 |
| Error | 111 | 0.25 | | | |

Even though there were different effect sizes by race when I ran an independent *t* test for the Self-Efficacy with Computers construct (see Table 4.6), there is virtually no difference between the mean scores for Latino/a and white students on this construct once the pre-survey scores were controlled (see Table 4.10). In other words, on average the race of the student was not a predictor of the post-survey scores once the pre-survey scores were taken into account.

***Repeated Measures Mixed Analysis of Variance***

Another way to look at the constructs by subgroup while accounting for differences in pre-survey scores is by using a repeated measures mixed ANOVA. Two repeated measures mixed ANOVAs were run for the same sub-population and construct combinations used for the

ANCOVA procedures as flagged by initial t-test and effect sizes calculations. One repeated measures mixed ANOVA was conducted to assess whether there were gender differences in pre and post-survey responses on the Maintained Interest due to Value construct. A second repeated measures mixed ANOVA was conducted to assess whether there were differences by race in pre and post-survey responses on the Self-Efficacy with Computers construct.

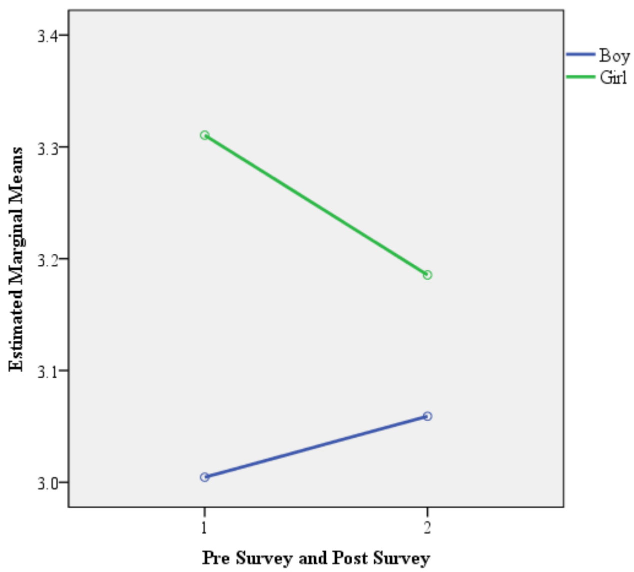
Unlike conducting separate independent and paired t-tests and then comparing them, a mixed repeated measures ANOVA includes both pre and post-survey results (within subject comparisons) in the model along with gender or race (between subjects comparisons). Assumptions tested for both ANOVAs included: independence of observations, normality, and sphericity. All assumptions were met.

Results indicated that there was a statistically significant main effect of gender $F(1, 115) = 5.17$, $p < .05$, partial $eta^2 = .043$, but not between pre and post-survey measures of the Maintained Interest due to Value construct $F(1,115) = .44$, $p = .51$, partial $eta^2 = .004$. There was also not a statistically significant interaction between gender and pre and post-survey administration $F(1, 115) = 2.84$, $p = .10$, partial $eta^2 = .024$. Table 4.12 displays the pre and post-survey means and standard deviations for the Maintained Interest due to Value construct by gender and Figure 4.1 graphically represents the interaction between gender and pre and post-survey means on the same construct. Upon examination of the figure it is apparent that while the mean of female responses falls and the mean of male responses rises between the pre and post-survey, the mean for female students is still higher than that of male students on the post-survey for this construct.

**Table 4.12 Means and Standard Deviations of the Pre and Post Survey Responses on the Maintained Interest Due to Value Construct Separated by Gender**

| | Females (N=62) | | Males (N=55) | |
|---|---|---|---|---|
| | M | SD | M | SD |
| Pre-Survey | 3.31 | 0.51 | 3.00 | 0.62 |
| Post-Survey | 3.19 | 0.55 | 3.05 | 0.68 |

**Figure 4.1 Change in Means from Pre to Post Survey on the Maintained Interest Due to Value Construct by Gender**



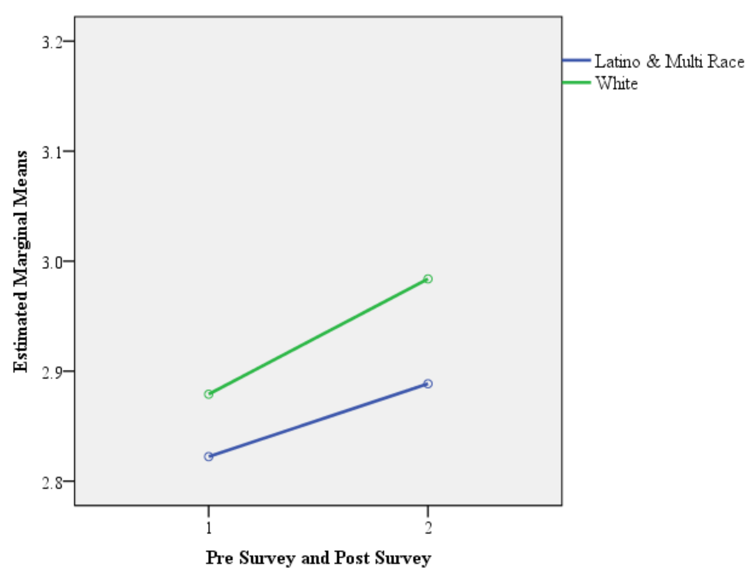

A second repeated measures mixed ANOVA was conducted to assess whether there were differences by race in pre and post-survey responses on the Self-Efficacy with Computers construct. Results indicated that there were no statistically significant main effects or interactions between race and pre and post-survey measures of the Self-Efficacy with Computers construct. The main effect of race was $F(1, 112) = .41$, $p = .53$, partial $eta^2 = .004$, and the main effect of pre and post-survey measure of the Self-Efficacy with Computers construct was $F(1,112) = 2.38$, $p = .12$, partial $eta^2 = .021$. There was also not a statistically significant interaction between race and pre and post-survey administration $F(1, 112) = .12$, p =

.73, partial eta$^2$ = .001. Table 4.13 displays the pre and post-survey means and standard deviations for the Self-Efficacy with Computers construct by gender and Figure 4.2 graphically represents the interaction between race and pre and post-survey means on the same construct. Upon examination of the table and figure it is apparent that both Latino/a and white students mean responses increased slightly between the pre and post-survey and the increases are on nearly the same slope. Thus there is no significant difference in the means for this construct when considering the students' races.

**Table 4.13 Means and Standard Deviations of the Pre and Post Survey Responses on the Self-Efficacy with Computers Construct Separated by Race**

| | Latino/a and Multi-Race (N=83) | | White (N=31) | |
|---|---|---|---|---|
| | M | SD | M | SD |
| Pre-Survey | 2.82 | 0.49 | 2.88 | 0.82 |
| Post-Survey | 2.89 | 0.55 | 2.98 | 0.89 |

**Figure 4.2 Change in Means from Pre to Post Survey on the Self-Efficacy with Computers Construct by Race**



**Summary**

While initially flagged by *t* tests and effect size calculations, neither the Maintained Interest due to Value construct by gender, or the Self-Efficacy with Computers construct by race, turned out not to be statistically significantly different on the post-survey upon further examination. There were no statistically significant differences overall or within any constructs or subgroups tested.

The stability of students' pre and post scores is reassuring when wanting to determine the current levels of students' interest, self-efficacy, and likely future pursuits in STEM related fields. This is Research Question #1 in this study: *What are students' current levels of interest and self-efficacy in technology and mathematics?* We can feel fairly confident that these are accurate and stable measures of students' opinions, feelings and values of these constructs when there is little change over time.

These findings also support Claim 2 in this research study: *Students' social addresses are not good indicators of their level of engagement, interest, and participation in these activities.* A student's social location including gender, race, and previous experience using the AgentSheets (which in this case also corresponds to student's previous performance in school mathematics classes) did not predict a student's interest, self-efficacy, and likelihood that s/he will pursue STEM content in the future. There were no significant differences by any of these descriptors between the pre and post-survey responses; gender, race, and previous mathematics performance did not indicate differences in interest and confidence in STEM content.

We can also use this information to address the sub-question RQ1.1: *In what ways does interest development differ for students with repeated experiences using the AgentSheets* *software*? Since there were no statistically significant differences between students with different levels of previous AgentSheets experience on the pre and post-survey, these results do not indicate that there is a difference in interest development for students with repeated exposure to the AgentSheets software. Qualitative data show other results as explained in Chapters 5 and 6.

The pre and post-survey analyses did not support Claim 1: *The Simulations in Statistics units developed and implemented help transition students' interest levels in technology and mathematics from triggered to maintained situational interest over time*. The pre and post-survey score comparisons did not show a significantly increased mean score in the Maintained Interest due to Value or the Maintained Interest due to Feeling constructs. There was also no significant change in the triggered interest construct shown in the survey analyses.

There are several possible reasons for these results. Even if students' interests had transitioned from triggered to maintained, the time between the two administrations of the survey may have been too short. There were only approximately six weeks between the two administrations and one of the weeks was a vacation week. Self-efficacy and deep beliefs about possible future career paths can take a considerable amount of time to change. A second possibility is that the survey instrument is not sensitive to small changes in interest. Further item development and testing may be warranted for future research. A third possibility has to do with the particular sample of students in this school. Because of elective classes using the AgentSheets software were offered to students not in the math classes that used AgentSheets simulation units as part of their curriculum the year before, there was cross contamination. It was hard to find a sizeable group of students for whom this was the first exposure to AgentSheets and any Sim-Stats units.

While Claim 1 was not supported by the pre/post-survey analysis of the selected response items, interview and open-ended response data provide valuable insight into the triggered and maintained interest constructs. Unlike survey administration, data collection using qualitative methods can expand on and probe into students' beliefs based on initial student responses. Follow-up questions and requests for elaboration on a given answer can provide valuable depth and background information. Chapters 5 and 6 describe findings from the portions of this study that rely on qualitative data collection methods.

# Chapter 5. Students' Perspectives on Simulation Design and Related Future Pursuits

In the following chapter, students' responses to the interview questions and open-ended survey items are reported by topic to address the main constructs of this study: self efficacy in mathematics and technology, triggered and maintained interest, and future pursuits. This chapter also reports students' overall experience using AgentSheets to complete the Sim-Stat project, and their feelings about using computer technology to help learn mathematics in general.

A representative sample was selected to match the population of the school as closely as possible. Students were selected for the interviews based on gender, race, and home language as well as prior experience using the AgentSheets software, which also corresponded to prior performance in mathematics classes. Teachers suggested students for interviews based on these considerations and then students were asked if they would be willing to be interviewed. Nineteen students were interviewed:

- 8 males, 11 females
- 12 Latino/a students, 7 white students
- 7 students whose home language is Spanish, and 11 students whose home language is English
- 14 students who had previously taken lower-level mathematics classes, and 5 students who had previously taken advanced mathematics classes

Though I asked that teachers suggest approximately the same number of students who had, and had not, taken remedial math, the sample ended up more heavily weighted with students who had been enrolled in Mr. Samson's remedial math classes (denoted as *AgentSheets Experts*). Five of the nineteen interviewed were considered AgentSheets Novices. See Table 5.1.

**Table 5.1 Interview Participants Demographics and Characteristics**

| Interview # | Pseudonym | AgentSheets Experience | Gender | Race | Home Language | Teacher |
|---|---|---|---|---|---|---|
| 1 | Alfredo | Expert | Male | Latino | Spanish | Ms. Avery |
| 2 | Veronica | Expert | Female | Latina | Spanish | Ms. Avery |
| 3 | Craig | Expert | Male | White | English | Ms. Avery |
| 4 | Pete | Expert | Male | Latino/ Mixed | English | Ms. Avery |
| 5 | Juan | Expert | Male | Latino | Spanish | Mr. Connor |
| 6 | Nina | Novice | Female | Latina/ Mixed | Spanish | Mr. Connor |
| 7 | Maddie | Expert | Female | White | English | Ms. Avery |
| 8 | Leo | Expert | Male | Latino | Spanish | Ms. Avery |
| 9 | Erin | Expert | Female | White | English | Ms. Avery |
| 10 | Adam | Novice | Male | Latino/ Mixed | Spanish | Mr. Connor |
| 11 | Karmen | Expert | Female | Latina | English | Mr. Connor |
| 12 | Cassandra | Expert | Female | Latina | Spanish | Mr. Connor |
| 13 | *Lia | Novice | Female | Latina | Spanish | Mr. Connor |
| 14 | *Pablo | Expert | Male | White | English | Mr. Connor |
| 15 | Amy | Expert | Female | White | English | Mr. Connor |
| 16 | Amanda | Novice | Female | White | English | Ms. Avery |
| 17 | *Grace | Expert | Female | Latina/ Mixed | English | Mr. Connor |
| 18 | *Damian | Expert | Male | Latino | English | Ms. Avery |
| 19 | *Kim | Novice | Female | White | English | Ms. Avery |

* Focal Participants

Interviews were conducted between the first and the second Sim-Stat units and were artifact-based, asking students to share their recently created and uploaded simulation as the starting point for the interview. I then followed the interview protocol (see Appendix B) in a semi-structured fashion, allowing for natural flow of conversation. All interviews were audio-recorded and fully transcribed.

Using an analytic framework approach (Patton, 2002, p. 439), I coded the fully transcribed interviews question by question, grouping responses from all interviewees by question asked. Within each of the groups of responses by question, I conducted a thematic content analysis (Krippendorff, 1980) to look for patterns and themes within the responses, combining and summarizing similar responses. These question groups were then clustered by larger construct to address the research questions in this study. For example, responses about self-efficacy in mathematics, self-efficacy in computers, and those addressing a student's previous AgentSheets experience level were grouped and analyzed together to address RQ 1: *What are student's current levels of interest and self-efficacy in technology and mathematics?* Table 3.3 in Chapter 3 shows which interview topics were aggregated into larger constructs for analysis.

This chapter first examines students' overall experiences during the Simulations in Statistics units. Then a summary of what students believed to be the most interesting and challenging aspects of the project is presented, followed by least favorite and favorite parts of the unit. Interestingly, challenging was not equivalent to least favorite for most students. This section is followed by the central focus of this chapter, students' interest in STEM courses and related careers. A summary of the self-efficacy beliefs of students in two areas, mathematics and computers, is then presented. In the next section, students' ideas about different uses for computers, using computers to learn mathematics, and students' metacognitions about their learning including the benefits of collaboration and use of online resource are presented. The chapter finishes with findings surrounding the future pursuits and intended careers of students at North Middle School.

**Overall Experience with Simulations in Statistics Units**

You get to design it the way you want it
Easy – anybody can do it
Seems hard at first
Get out there – others can see and play something you create
Computer instead of working on paper
Not more of a book thing
Hands-on
Frustrating - You got to figure it out,
so you learned a lot from it
Thought it was gonna be lame - I tried it and I really liked it
Visualization so I remember it better
More interesting than regular math
There's no way to test the trees in real life, there is a way on AgentSheets
Seeing what could really happen without really being there
Not just a game, it also teaches you

Students were asked about their overall experience with AgentSheets that school year, including interesting and challenging aspects and favorite and least favorite components of the unit. Autonomy and personalization emerged as important aspects of the Simulations in Statistics units. Students appreciated being able to create the simulation by their own design, "you get to design your own characters and you get to, like, design the worksheet, like, the way you want it" (Interview #12). Students found the challenge of creating a simulation from scratch both frustrating and enjoyable. Fifteen of the nineteen students interviewed (approximately 79%) said that the initial programming of the behaviors was the most challenging part of the creating the simulation. Veronica replied, "The behaviors. That was the hardest part, because if you messed up on one thing, you had to restart it again, and you had to redo it. I had to go back and figure out where I had messed up and things" (Interview #2). Debugging was the second most commonly named challenge. Thirteen of the nineteen students (approximately 68%) mentioned the challenges of debugging. While students initially found programming and debugging difficult, they had learned a lot in the process and were proud of the results of their efforts. Many students found that these challenges made the project more interesting and worthwhile.

Pablo shared how running his forest fire simulation for the first time had been his favorite part, "once it all started burning, it got kind of exciting" (Interview #14). Grace related,

> … that actual part when you watch it all go down, all of it burn, that was my favorite thing, 'cause, like, you're seeing everything that you've done. It might have been hard, but you see it all come together, and that was really neat. (Interview #17).

This seemed to be a moment of accomplishment and pride for these students. They had begun with a blank worksheet and had created a working simulation within one week. Furthermore, students related how these simulations were powerful and authentic.

The realistic nature of the simulation and the application of the learning to an imaginable context were reported to increase student interest in the project. Adam said, "I think it was fun just creating the trees and then afterwards it was surprising how it was related to math" (Interview #10). When tying this to their mathematics classes, many of those interviewed talked about how these lessons were more interesting than "regular math." Student responses indicated that interaction between technology and mathematics to immediately apply learning was key to student interest. Kim stated, "I like the online stuff and I like the visualization, 'cause, like, if I'm just, like, handed a paper on how to do something, I'm always like, 'I don't want to read all that.' I like having it explained in pictures better. It's easier to see it and it's fun, so you … remember it" (Interview #19). When an integral part of the lessons included designing, creating, and solving authentic problems using technology, both interest and learning were high according to student responses.

Some students particularly enjoyed the data analysis portion of the unit. "Creating the things and doing the math at the end" were Adam's favorites because, "on quizzes you don't really get help much, but on this one you got a lot of help" (Interview #10). This referred to the fact that students collaborated on all aspects of the unit and got immediate feedback from peers and teachers on their work. Most students reported enjoying being able to interact with peers during these units.

Other students stated that the mathematics portions of the unit were their least favorite part. Maddie said, "I didn't like putting together the graph or finding the line of best fit. That took me a while" (Interview #7). Other least favorite parts included having to write out answers to the reflection questions at the end of the unit and being asked by peers to help when the student felt like they had only nascent understanding themselves. For example Grace commented, "I barely got through it myself, so I couldn't really help them. I didn't know how to" (Interview #17). When students felt they had a deeper understanding of the project themselves, they were more likely to report enjoying assisting others.

Students liked the fact that the simulations were posted for others to see if they chose to share with friends or family outside of school. Amanda accounted, "It was like just being able to get out there and be part of something that you create and that you can play and that others can see" (Interview #16). Yasmin Kafai (2012) termed these types of products *socially* *shared artifacts* and described how social aspects of programming are becoming central to online programming communities.

A few students said that they enjoyed all aspects of the unit. Karmen, a female Latina student, stated, “I love math, math’s my favorite subject, and I liked doing the math part and everything, so I really didn’t have a least favorite” (Interview #11). These responses could have been influenced by the fact that I was interviewing them and I had taught a good portion of the unit. Perhaps they did not want to disappoint me as the teacher and project representative. This did not sway one student from sharing her opinion, however; Cassandra said that her least favorite part of the unit was when “the teachers talk and talk and talk and [the students] just sit there” (Interview #12). This is a good take-away message for many teachers, including myself.

There is also the possibility that these students were not overly influenced by me interviewing them and genuinely enjoyed all aspects of the units. One of the questions for this study was: Did this enjoyment translate into an increased interest in STEM fields? This is the topic explored in the next section.

**Interest in STEM**

Merriam-Webster defines interest as a noun as “a feeling that causes special attention to an object”, or in its transitive verb form to interest is “to engage the attention” (Merriam-Webster Online Dictionary, 2012a). As in this definition, the intuitive or common understanding of interest often stops with initial catching of the interest or triggered interest. In this study, I examine the transition of initially triggered interest to a different state where that interest is maintained over time or through repeated exposure, or even individualized to become an on-going self-sustained interest.

To explore the level of student interest in STEM fields, and how this interest may or may not have been influenced by their experiences in the Simulation in Statistics units, students were asked about their prior year's math class enrollment. If they had taken Mr. Samson's class during their $7^{th}$ grade year, they had already used the AgentSheets software to design and create a Frogger style game and a virus spread simulation. Students who had been enrolled in these classes in the prior year were then asked how they thought this previous experience influenced what they did this year or how they approached the simulation differently this time.

Most students responded that it had made this time using the software easier and that even though they may not have remembered how to code the behaviors when they started using the software again, this knowledge came back more quickly than the initial learning curve in the previous year. Students also discussed being able to take their simulation further this time around by adding more features or actually being able to complete the simulation in the allotted time in the computer lab.

There was also evidence of students' interest types changing over time. Some students discussed experiences that indicated a shift from Triggered Situational Interest to Maintained Situational Interest. Others gave examples of experiences that indicated that their behavior would be characterized as staying in a Maintained Situational Interest over a longer period of time, for example from the previous year through the current year. We must first define what is meant by these terms.

I will be using process-oriented definitions of interest that conceptualize interest as being a psychological state rather than an enduring disposition (Hidi & Renninger, 2006; Krapp, Hidi, & Renninger, 1992). Hidi & Renninger (2006) define Triggered Situational

Interest as a "psychological state of interest that results from short-term changes in affective and cognitive processing" (p. 114). Triggered interest is described as being sparked by the environment, catching students' interest while being externally supported. Instruction or learning environments that include collaboration, group work and computers are often associated with high levels of triggered situational interest (Hidi & Renninger, 2006). The learning environment for the Sim-Stats units could easily be described as having these same characteristics, and thus, one would expect high levels of triggered interest during the units.

Maintained Situational Interest is defined as a "psychological state of interest that is subsequent to a triggered state" that "involves focused attention and persistence over an extended episode in time and/or reoccurs and again persists" (Hidi & Renninger, 2006, p. 114). Linnenbrink-Garcia et al. (2010) split maintained interest into two components: maintained interest due to feeling, in which the material is enjoyable and engaging in its own right, and maintained interest due to value, in which students view the material as personally important and believe it is valuable now or in the future. Maintained interest due to feeling or value is described as being held or sustained, but still externally supported. Therefore, a transition from triggered to maintained interest would involve interest over a longer period of time or repeated episodes of interest, but there does not need to be evidence of this interest being internally motivated, as both triggered and maintained are considered to be externally supported.

As you may recall, Claim 1 (The Simulations in Statistics units developed and implemented help transition students' interest levels in technology and mathematics from triggered to maintained situational interest over time) was not well supported by the pre/post-survey analysis of the selected response items as described in Chapter 4. However, interview and open-ended response data provide valuable insight into the triggered and maintained interest constructs. Unlike the pre and post-survey administration, during the interview process I was able to ask follow-up questions to probe students' experiences and go beyond initial student responses. This provided valuable depth and background information.

In the following sections, excerpts from the interviews show evidence of students' psychological states of interest and, for some, transitioning from one state of interest to another. The survey responses for each of these students on the constructs of interest are also provided below; it becomes apparent though, that the survey instrument, in the way that it was administered in this study, may not be sensitive to *changes in states of interest* for most students.

**Triggered Situational to Maintained Situational Interest**

To illustrate the triggered interest state and triggered to maintained situational interest changes, I will draw from the interview comments from three students: Erin (Interview #9), Karmen (Interview #11) and Pete (Interview #4). Erin's shared experiences exemplify a triggered situational interest state, while Karmen and Pete described their experiences in a way that could be interpreted as moving from a state of triggered interest to a state of maintained interest.

When Erin was participating in a Sim-Stat unit, she shared that she was interested and computers seemed easier than she initially thought they would be. Erin stated, "I didn't know that simulations on computers would be this easy. I thought they were really hard. Last year, in Mr. Samson's class I was confused on what to do, but this year I got my memory refreshed and it was a lot easier." Though her interest was triggered when participating in the units, her interest did not seem to have transitioned to a maintained situational interest level. By self-report, she found the Sim-Stat unit difficult and confusing last year, but this year, she relayed, it had been easier and triggered her interest.

When considering Erin's survey means on the triggered and maintained situational interest though, both triggered and maintained interest means of responses increase from pre-survey to post-survey. Erin's pre-survey mean for the triggered interest construct was 1.8 (SD = 1.0). This increased by 1.4 for a post-survey mean of 3.2 (SD = 0.4) on the triggered interest construct. Similarly, Erin's pre-survey mean on the maintained situational interest construct 1.7 (SD = 0.9). This mean increased by 1.8 for a post-survey mean on the maintained interest construct of 3.4 (SD = 0.5). Erin was one of a relatively few students with significant changes in post-survey means; on the maintained interest construct, the t-test results showed significant change $p < .01$ with a large effect size of $d = 2.8$ [6]. For most other students, the means remained fairly constant between pre and post-survey.

While Erin's shared experiences indicated that she had not shifted beyond the triggered interest state, Karmen's and Pete's comments show evidence of a shift in their interest states from triggered to maintained. Karmen's interest started as triggered situational interest during the Sim-Stat unit during her 7$^{th}$ grade year. She discussed how she didn't like using a computer much at first, but that over the course of the unit she changed her mind when she "figured out how good they were." Then Karmen's account began to shift, illustrating a shift in interest state. Karmen talked about how she began to attempt a wider range of programmed behaviors when creating her simulation this school year. She was no longer intimidated by a self-perceived lack of knowledge. She stated, "Last year, I was just scared to do things I wanted, but this year I'm like, 'You know what? Let's just do this.'" Karmen had enjoyed her

[6] For Cohen's *d* an effect size of 0.2 to 0.3 might be considered a "small" effect, 0.4 to 0.7 a "medium" effect, and 0.8 and greater, a "large" effect. *d* can be greater than 1. (Cohen, 1988).

first experiences in the Simulation for Statistics units last school year, but upon repeated exposure she gained the confidence to attempt new challenges. Her interest had shifted to one that was characterized by "focused attention and persistence over an extended episode in time and/or reoccurs and again persists" (Hidi & Renninger, 2006, p. 114), in other words, she had entered a maintained situational interest state.

Likewise, Pete began by commenting about parts of the unit that caught his interest. He stated, "The most interesting part was, like, makin' the trees and getting the settings right to make a simulation to go on the Internet so people could play my game." The fact that Pete could show others outside of class his simulation seemed to be key in the shift of his interest from triggered to maintained situational. He discussed how he wanted to do even more than just show off his simulation in an applet version; he wanted to be able to continue working on the simulation at home. He stated, "On my computer, you can't go on the AgentSheets stuff [7]… I was gonna edit to take off that [pointing to his simulation] … but I couldn't do that." Once the student is interested in repeated or maintained interactions with the content, this interest can be considered as being in a maintained interest state. Pete's comments show movement from triggered to maintained interest.

Although the responses shared by Karmen and Pete indicated a shift in interest, when considering their survey means on the triggered and maintained situational interest constructs, means of responses remained relatively constant from pre-survey to post-survey. Karmen's mean score for the triggered interest construct was 3.8 (SD = 0.4) on both the pre and post-survey. Karmen's pre and post-survey means on the maintained interest construct were also

[7] The program was offered to students for purchase at a discounted price, but this did not happen for many students. Several students used shared computers at the school or library, so loading a program was not an option on these machines. For others, the cost may have been prohibitive even at a reduced price. Another possibility is that purchase information never reached the parents. Software purchase information or the order form may have needed to be provided in a flyer for parents in both Spanish and English.

very close to the same value. Karmen's pre-survey mean on the maintained situational interest construct was 4.0 (SD = 0). This mean decreased by 0.1 for a post-survey mean on the maintained interest construct of 3.9 (SD = 0.3). As with most other students, Karmen's means remained fairly constant on the interest constructs between pre and post-survey.

Pete's post-survey means on the triggered and maintained situational interest dropped slightly from the pre-survey means on these constructs. Pete's pre-survey mean on the triggered situational interest construct was 2.8 (SD = 0.4). This mean decreased by 0.4 for a post-survey mean on the triggered interest construct of 2.4 (SD = 0.5). Likewise, Pete's pre-survey mean on the maintained situational interest construct was 2.9 (SD = 0.3). This mean decreased by 0.5 for a post-survey mean on the maintained interest construct of 2.2 (SD = 0.4). Only the difference between the pre and post-survey maintained interest mean was significant at the $p < .01$ level (Cohen's $d = 1.6$). (The mean difference was not significant, $p = .18$, $d = 0.8$). However, what is somewhat unique about Pete's scores is that both of his post-survey scores dropped below the 2.5 halfway point. In other words, Pete's pre-survey means were in the "agree" half of the scale whereas his post-survey scores were in the "disagree" half of the scale. The quantitative results were contrary to the experiences he shared in his interview.

**Maintained Situational Interest**

While Karmen and Pete's comments showed evidence of recently moving to maintained interest, other students discussed experiences that could be characterized as staying within a maintained interest state throughout the school year in which the study was conducted. Below are excerpts from interviews with Damian (Interview #18), Grace (Interview #17), and Maddie (Interview #7). These students likely transitioned to the maintained interest state during the previous school year's Sim-Stat units.

Damian discussed how he had been using the Scalable Game Design Arcade (where student simulations and games created using AgentSheets are uploaded) at home, "I've actually been dabbling a little bit at my house with AgentSheets, showing my little brother and stuff, and he liked it, too. I was just lookin' around on the Internet, checkin' out some of the stuff people have built." Grace also discussed how she would like to show her siblings her simulation and other projects created by students in her class, but that she had difficulty getting into the site from home. She said, "I'd like to show my little brother, he's in second grade, and I know that he'd probably think that was really cool, but it'd probably be hard for him … I've tried it once, and I think that I don't know what happened, it was a long time ago. It wasn't working right. I'll try again tonight." Maddie also made a family connection when she talked about how she might be interested in a career in technology. She discussed how her father had earned a degree in technology and so she had his support for her interest in computers, "He said it was really fun for him, it was a great experience, and it'd be really fun to do something like this, learn more about it, so it wouldn't be as hard as it is now." For several students, including Damian, Grace, and Maddie, the bridge between home and school seemed to be important for helping to transition their interest from triggered to maintained. Damian, Grace, and Maddie began the transition from triggered to maintained situational interest in their first year of Simulation in Statistics units, and remained in a maintained interest state throughout the time period of this study.

When looking at the pre and post-survey results for Damian, Grace, and Maddie, there is not much evidence of movement in interest states. None of the differences in means were significant, and the effect sizes were negligible. Table 5.2 shows the means and standard deviations for these three students on the triggered and maintained situational interest constructs.

**Table 5.2 Means and Standard Deviations of the Pre and Post-Survey Responses on the Triggered and Maintained Interest Constructs by Student**

| | Triggered Situational Interest | | Maintained Situational Interest | |
|---|---|---|---|---|
| | Pre-Survey Mean (Std. Dev.) | Post-Survey Mean (Std. Dev.) | Pre-Survey Mean (Std. Dev.) | Post-Survey Mean (Std. Dev.) |
| Damian Interview 18 | 3.2 (0.4) | 3.8 (0.4) | 3.2 (0.4) | 3.3 (0.5) |
| Grace Interview 17 | 3.4 (0.5) | 3.6 (0.5) | 3.0 (0.0) | 2.7 (0.7) |
| Maddie Interview 7 | 2.8 (1.2) | 2.8 (1.2) | 3.0 (0.9) | 3.1 (0.7) |
| Juan Interview 5 | 3.8 (0.4) | 4.0 (0.0) | 4.0 (0.0) | 4.0 (0.0) |

Overall, the pre and post-survey measures do not seem to capture the same data collected in the qualitative interviews with students. Triangulation of data sources seems particularly valuable for understanding the interest constructs.

**Maintained Situational to Emerging Individual Interest**

Individual interest can be characterized by concrete actualized behavior such as, “focused, prolonged, relatively effortless attention … accompanied by feelings of pleasure and concentration” (Krapp, et al., 1992, p. 7). Hidi & Renninger (2006) define individual interest in two levels: emerging and well-developed. Emerging individual interest is described as “the beginning phases of a relatively enduring predisposition to seek repeated reengagement with particular… content over time” (Hidi & Renninger, 2006, p. 114). A learner in this phase of interest still may need support from the environment such as encouragement and direction when confused or facing difficulty with the task. In this way, the learning environment can aid in further development of individual interest. A well-developed individual interest is characterized by the student having a "relatively enduring predisposition to reengage with… content over time" (Hidi & Renninger, 2006, p. 115). The student can be said to be in a state of Flow (Csikszentmihalyi, 2008) where effort is required, but it often seems effortless to the student.

Responses from a couple of students indicated that they had shifted from maintained situational interest to emerging individual interest, and one interviewed student described experiences that would characterize his interest as being a well-developed individual interest. The following vignette summarizing Juan's responses illustrate his transition from a psychological state of maintained interest to one of emerging individual interest.

Juan (Interview #5) was a 14-year-old Latino student whose home language was Spanish. He was in Mr. Samson's lower level mathematics class last year indicating that historically his performance in mathematics was lower among his peers. He was also considered an AgentSheets Expert because of his previous exposure to the Simulation in Statistics units and his level of comfort using the AgentSheets software. Juan did not have access to a computer at home and used the computers at the public library to complete his schoolwork. The Simulation in Statistics units presented a challenge for Juan during the previous school years. He mentioned that he had not completed his simulation or his game while in Mr Samson's class. Juan also enrolled in an elective class using AgentSheets. In this class he created a Sokoban game but he said, "I finished that one, but I think I did something wrong, because every time I wanted to go to the next level, it wouldn't go to the next level." Even though he had completed programing the game, he did not have enough time to successfully debug the code to allow it to run correctly.

During the school year of this study, Juan discussed how he was able to complete his projects and they ran as expected. This was a point of pride and a turning point in his interest. He stated,

> I've been challenged a lot with those past two years of not finishing a game and just me being focused and ready to actually finish a game. It feels pretty good, actually, when you finish. When you don't finish, it's kind of disappointing, but I finished this one and it turned out great, so I'm pretty proud of myself. (Interview #5).

When asked about what he thought changed that allowed him to complete the projects now, he stated, "It's probably 'cause I wasn't as experienced as I am right now with computers, because over the years I've been actually working with computers a lot, and I've gotten to understand them way more than I used to." Repeated exposure was key to Juan's success.

Juan's pride in his accomplishments fueled his interest in continuing with this type of work. He was impressed that this type of simulation and game creation was something that he and his peers could successfully create.

> I didn't know it would be in our reach to be able to make games like this. It was a pretty fun experience doing this, 'cause I've always wanted to create a game on a computer, and I always have wanted to create games period. Like, I go home and I play my video games and I see what they do and it's pretty cool, and I want to be making games like that. (Interview #5).

Juan went on to discuss how he had been enrolled in a program at school where students selected and researched which careers they were interested in. Juan said that he chose that he wanted to "work in technology and computers and stuff like this," going on to say,

> I've always had an interest for technology. It's always been the one main thing I've done in my life. It's pretty fun being on the Internet, but I've never really heard of AgentSheets until I've been to this school, and honestly, every time I go to the library I always look for AgentSheets, but I never know how to get it because it's not on their computers, 'cause it's just the library and not the school. (Interview #5).

Juan was in an emerging individual interest state during the study period. He had identified that this was a career path he wanted to research and pursue, and was seeking out additional opportunities to interact with the content. He was reporting feelings of pleasure and concentration and a desire to continue this work. Emerging individual interest still benefits from support from the environment. What could greatly influence Juan's transition to a well-developed individual interest state is future access to computers, programming software, and further instruction to support his interests.

Juan's pre and post-survey means and standard deviations are listed in Table 5.1. The change in means was not significant for either interest construct as Juan started out with a very high interest in math and technology and this interest remained high on the post-survey as well.

Juan was classified as an AgentSheets Expert due to his past experiences using the AgentSheets software. This classification and its potential impact on interest development was one focus for this study. A sub-question to research question one is "Does interest development differ for students with repeated experiences using the AgentSheets software?" In Juan's case, the answer to this seemed to be that with repeated exposure, his interest shifted from triggered situational, to maintained situational, to emerging individual interest. The question of whether this is a pattern that holds across students by their previous experience levels is one that I address in the next section.

**AgentSheets Experience Level**

Initially I thought that it would be easy to separate the students into two groups: those with previous AgentSheets experience (AS Experts) and those without previous AgentSheets experience (AS Novice). This would be a matter of determining if they had had Mr. Samson, who had used AgentSheets in his math classes, or if they had taken Mrs. Garfield for math, who had not used AgentSheets. Since these were the only two teachers for 7$^{th}$ grade math at this school, all students had to take one or the other. All students who attended NMS in 6$^{th}$ grade and were not in band had some exposure to AgentSheets in their 6$^{th}$ grade Spanish class. Students had used AgentSheets to create a game to practice Spanish vocabulary words. Since nearly all students had had exposure to this short and rather unrelated unit, I decided this alone would not change the grouping of AS Expert and AS Novice.

However, there was one more complicating factor that I had not counted on. There was an elective class offered using AgentSheets for game design. Several of the students who had taken Mrs. Garfield in 7$^{th}$ grade math class also enrolled in this elective course, giving them prior exposure to programming in AgentSheets. In fact, some students took the class two trimesters and had a more in-depth experience than those who had only used AgentSheets in Mr. Samson's math classes. Therefore, determining AS Expert and AS Novice categories became more complicated, and I had a smaller pool of AgentSheets Novices than originally anticipated. Nonetheless, through the interviews, I was able to ask clarifying questions around students' prior AS experience. Through analysis of their interviews combined with their responses to their surveys, I was able to code the student as either AS Novice or AS Expert.

According to students, prior experience had a positive influence on their understanding, self-efficacy, and even maintained interest for some. Eleven of the 14 (approximately 79%) "AgentSheets Expert" students commented that having had prior AS experience made this project easier for them to complete. See Positive Influence section of Table 5.3.

**Table 5.3 Influence of Prior AgentSheets Experience on Subsequent Project**

| | Student | Quote from Interview |
|---|---|---|
| **Positive Influence** | | |
| | Nina (Interview #6) | "It was helpful because you knew what to do and you knew, kind of, how to work it already. It was easier." |
| | Veronica (Interview #2) | "It helped me—I already knew kind of what I was doing, but since [last year] was a virus [simulation] and this [year] was a forest fire [simulation], I just had to do it in different ways." |
| **New Understanding** | | |
| | Cassandra (Interview #12) | "I knew what we were doing. Then [last year] I didn't know what we were doing until the end" |
| | Amy (Interview #15) | "It was a little bit easier than the first time… I knew what I was supposed to be doing. The first time I didn't really get it" |
| **Somewhat Helpful** | | |
| | Alfredo (Interview #1) | "[prior experience helped] a little bit, but I didn't remember a lot" |
| | Erin (Interview #9) | "once my memory refreshed, I kind of knew what everything was, but… half of me knew what to do and half of me didn't know what to do, so I'm kind of like in between" |

These students felt more confident in the use of AgentSheets and computers. For example, a student who had been in Mrs. Garfield's math class, Pablo (Interview #14), talked about how he had already completed a Pac-man-style game in the elective class. Mr. Connor had given Pablo an alternate assignment for the second AgentSheets unit this year in math class; he was to create his own game. Pablo exhibited high self-efficacy with AgentSheets and computer use and his willingness to take on a greater challenge. He stated, "I made Pac-man and Space Invaders. So, it was pretty much easy for me doing all that. So, Mr. Connor wants me to do something even harder… I'm gonna make a shooting [game] … It's gonna be kind of difficult." The degree of positive self-efficacy and confidence from students' prior experiences had an impact on students' interpretation of degree of difficulty of the unit during this school year.

Six of the 14 (approximately 43%) "AgentSheets Expert" students commented that they were surprised by how well they had done and how much they were able to accomplish on this unit after having a more difficult time in the past. See New Understanding section of Table 5.3. Approximately 21% (3 of 14) students felt that having prior experience was helpful, but they still did not feel completely confident in the use of the software at the beginning of the unit. They did tend to say that they remembered aspects of the software fairly quickly once they were immersed in the work. See "Somewhat Helpful" section of Table 5.3. There seemed to be a cumulative effect of exposure to computer use and the AgentSheets software.

Students with no prior experience using AgentSheets did mention that they felt they had to catch up, but that this was not too difficult. Most of the students with no prior experience had taken math from Mrs. Garfield and she taught the advanced math courses. Perhaps students from these classes tended to be able to excel academically and that helped them with their learning the AgentSheets software quickly. A few of these students even became resources for students who had used AgentSheets in prior years.

## Confidence and Self-Efficacy in the Use of Technology and Mathematics

### Self-Efficacy

Perceived self-efficacy has been defined as the "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 3). Students' beliefs in their efficacy influence the activities they choose to engage in, how long and to what degree they persist in their attempts at success in a given area, and eventually the level of success they achieve in a given area. Repeated exposure to an activity with success leads to higher self-efficacy in that area, which can lead to greater interest development. Bandura explains that "The satisfactions derived from goal attainments build intrinsic interest" (1997, p. 219). Thus, students categorized as AgentSheets Experts had more opportunities to develop high self-efficacy with computers, in particular with design and programming using the AgentSheets software. If a student does not feel self-efficacious in a particular area, maintained situational or individual interest is not likely to develop; whereas, shifts to higher interest states are more likely to occur for students with high self-efficacy in that area.

#### *Self Efficacy with Computers*

Evidence of students' feelings of self-efficacy with computers was collected from comments made during interviews. Students were not asked directly about their self-efficacy with computers. Additional evidence of self-efficacy with computers and mathematics was collected from the student pre and post-surveys.

Overall students' interview responses on questions about their confidence and perceived abilities using computers and the AgentSheets software showed relatively high self-efficacy for most students. Statements like, "I like working with computers. I really like it. I am a computer person" (Interview #15), and "I've always loved computers… it's pretty much all I do" (Interview #3), show that these students feel a high degree of self-efficacy and are defining personal identities in a way that includes the use, comfort with, and ability in technology. Others expressed their self-efficacy with computers in their ability to help other students in class. Damian, a male Latino student commented, "I had already finished. I would walk around and help them program, make sure everything was programmed correctly" (Interview #18). If Damian did not feel a high degree of self-efficacy in computers and with the AgentSheets software, he would be less likely to state that he could make sure that the code in others students' simulations was correct.

There were some students who expressed lower self-efficacy with computers, though even those who indicated that they were not as confident in the use of computers would limit this to sub-areas in which they believed they were less capable. For example one male Latino student, Pete, described how he was not very good at typing. At first he said, "I am not very good with computers" and then he corrected himself saying "well I'm good with computers; I'm not good at typing things" (Interview #4). Often, comments that could be considered as students having lower self-efficacy had to do with access and experience. If students did not have access to technology at home and the related experience of time spent on computers, they expressed lower self-efficacy in computer use. Other students reported lower self-efficacy with computers, but explained how this experience had disrupted those beliefs. Grace, a female Latina student stated, "I'm not very good on technology, so it was really surprising when I was able to do this… With the technology thing, I realized that it's not as hard as I thought it would be. It's a lot easier. Something I could definitely use in the future" (Interview #17). Overall, self-efficacy beliefs with computers were high, perhaps indicating the omnipresence and importance of technology; something that they not only *could* use in the future, but something they *must* use in the future.

***Self Efficacy in Mathematics***

Evidence of students' feeling of self-efficacy with mathematics was also collected from comments made during interviews, as students were not asked directly about their perceived self-efficacy with mathematics. Additional evidence of self-efficacy with mathematics was collected from the student pre and post-surveys and video and audio recordings of students in classes. There was a wider range of reported self-efficacy beliefs with mathematics than for computer use, and the two did not correlate well. In other words, students with high self-efficacy in mathematics did not necessarily report high levels of self-efficacy with computer use, and those with lower self-efficacy in mathematics did not necessarily have low self-efficacy with computers.

Although there is much current emphasis on STEM education, putting Science, Technology, Engineering and Mathematics in the same category, some students clearly delineated these areas as being quite different. Alfredo, a male Latino student stated, "I think I can do both science and technology, but not math" (Interview #1). Computer use was often seen as enjoyable, whereas mathematics was typically characterized as paper and pencil work that was tedious and repetitive. Some saw using a technology as a way to make the mathematics more palatable. Pete commented,

> It's better to do it on the computer instead of on a piece of paper on a worksheet or something, 'cause on the computer it gives you more to want to do more math, and there are some people that don't like doin' math, and I think it'd be

better for them to do it on the computer so they could like it more. [*Interviewer: Do you usually like math?*] Not really. (Interview #4).

Lia, a female Latina student, agreed with this sentiment, stating that using simulations and modeling real world phenomena using computers was more enjoyable than "other math"; she went on to explain that in "other math you just have to write and stuff, but this was fun" (Interview #13). This same student, as we will see in Chapter 6 (see Lia's vignette), spoke aloud to herself while taking the pre-survey. She was very clear in this narrative that she did not feel efficacious in mathematics, though she felt confident in her use of computers. During work time she offered to help fellow students with the programming aspect of their projects, but did not offer this support during the statistics and mathematics portions of the unit.

Other students saw mathematics and computer use as more related and enjoyed the combination of the two in the Simulation in Statistics units. Maddie, a white female student, shared that her favorite part was the data collection and analysis portion of the unit, "Putting together the [Excel] worksheet was really fun for me even though the questions that we had to answer, even though it was hard. I liked testing different densities. I thought that was pretty cool, too" (Interview #7). Like this student, quite a few students reported high levels of self-efficacy in mathematics. (See Table 5.3).

As with computer use, high self-efficacy could have been expressed as a willingness and ability to help other students with their mathematics work ("I usually help people, because in class I'm the first one to be done most of the time" (Interview #10)), or by stating directly that they enjoyed the subject ("Doing the math is easy" (Interview #5) and "Math's my favorite subject… I liked doing the math part" (Interview #11)) and/or that they planned on seeking future opportunities to engage in mathematics related learning activities. Students who identified mathematics related careers as ones they were considering, such as becoming a math teacher, also demonstrated high self-efficacy in mathematics.

***Self-Efficacy by Gender and Race***

When considering sub-populations by gender, there was not much difference between male and females on the self-efficacy with computers and mathematics constructs. Both female and male students expressed relatively high self-efficacy with computers and technology use. As mentioned previously, comments that could be considered *students showing lower efficacy* had more to do with access and experience than with gender. If students did not have access to a computer at home, regardless of their gender, they were more likely to express lower self-efficacy in computer use. There was not much difference in self-efficacy statements by gender in mathematics either. Female and male students also expressed self-efficacy in about the same range for mathematics. Some male students felt high self-efficacy in mathematics, while others felt lower self-efficacy in mathematics. This ratio of high to low self-efficacy comments was not markedly different for female students than for male students; some female students felt high self-efficacy, while others reported lower self-efficacy in mathematics.

When considering sub-populations by race, however, there was a difference between the reported self-efficacy in mathematics and computers for Latino/a students compared with white students. Higher self-efficacy in both mathematics and computer use was reported by white students than Latino/a students regardless of gender. Eleven Latino/a students commented on self-efficacy beliefs in mathematics and computer use. Of these, 6 students (approximately 55%) reported relatively high self-efficacy in computer use and 3 students (approximately 27%) reported lower levels of self-efficacy in computer use. In contrast, of the

6 white students who commented on self-efficacy, all 6 (100%) reported high self-efficacy beliefs in computer use.

In the area of mathematics, 4 of the 11 Latino/a students (approximately 36%) reported relatively high self-efficacy beliefs; with 6 of the 11 Latino/a students (approximately 55%) reporting lower self-efficacy beliefs. For white students, 3 of the 6 (50%) reported high self-efficacy in mathematics and none of the 6 white students reported low self-efficacy beliefs. See Table 5.4.

**Table 5.4 Self-Efficacy in Computer Use and Mathematics by Race**

| | **Self-Efficacy in Computer Use** | | **Self-Efficacy in Mathematics** | |
|---|---|---|---|---|
| Race: | Percent High (n) | Percent Low (n) | Percent High (n) | Percent Low (n) |
| Latino/a (n=11) | 55% (6) | 27% (3) | 36% (4) | 55% (6) |
| White (n=6) | 100% (6) | 0% (0) | 50% (3) | 0% (0) |

Note: Percents do not sum to 100% as not all students interviewed commented on self-efficacy beliefs.

As we may recall from Chapter 4, this pattern of lower self-efficacy for students of color in both computer use and mathematics was seen in the survey data as well. The largest difference in means when comparing students by race and construct was between Latino/a students (mean = 2.75) and White students (mean = 2.97) on the Self-Efficacy with Mathematics construct (delta mean = 0.22). See Table 4.7 for more details. Though the differences were not statistically significant, on average[8] white students reported higher self-efficacy in both computers and mathematics on the pre and post-surveys.

Lower self-efficacy for students of color in mathematics in particular has been explored in the context of stereotype threat research. Steele defines stereotype threat as “the event of a negative stereotype about a group to which one belongs becoming self-relevant, usually as a

[8] “On average” is used to indicate that this is not necessarily true for all students individually, but is reported as an aggregate over the students participating in the surveys and/or interviews.

plausible interpretation for something one is doing … that has relevance to one's self-definition" (Steele, 1997, p. 616). Steele (1997) and Osborne (Osborne, 2001, 2007) discuss how students of color and females are affected by stereotype threat in math-related fields including computer technology. Because of stereotype threat, students of color and female students may deidentify with these areas and not include them in their self-definition. Steele states that once deidentification happens "the person is likely to avoid the domain because of disinterest and low confidence" (Steele, 1997, p. 617). Then, even if this person does not do well in these areas, deidentification protects their self-regard.

The reports of self-efficacy in mathematics and computers for students of color participating in the Simulations in Statistics units seemed to be in line with research on stereotype threat, with students of color reporting on average lower self-efficacy than white students. These qualitative analysis results also align with this study's pre-post-survey analysis results for the self-efficacy constructs discussed in the Subgroup Response Analysis: Race Comparisons section of Chapter Four. However, when considering students of the same race, there were more students reporting high self-efficacy than low self-efficacy in computer use for both Latino/a and white students. The pattern of stereotype threat for females in both mathematics and technology and students of color with the use of computer technology did not seem to hold in this study.

One of the ways that this pattern may have been disrupted is by students coming to see computer use in a different light. By redefining perceived uses for computers and the ways in which students interact with them, we can create a new area in which to build self-efficacy beliefs. Even if students had low self-efficacy in traditional mathematics and/or technology, in this new platform, there are new ways of thinking and a new context or domain for self-efficacy beliefs. Because self-efficacy is highly domain specific, new opportunities are developed for alternate definitions of self-efficacy by expanding the perceived applicability and personal uses of mathematics and technology. Students were asked if participating in these units enabled them to think differently about the ways computers could be used.

***Thinking Differently about Computer Use***

In the interviews and in the post-survey, students were asked “How did AgentSheets make you think differently about ways to use computers?” By asking students this question in both formats, interview and survey, we are able to compare responses given in each format. I was also able to collect responses from the entire group of students involved in the Simulation in Statistics units as well as the 19 students selected for the interviews.

*Survey responses*

There were 118 survey responses to this question. The majority of students, approximately 82%, responded that participation in this unit made them think of computers in a more positive light. Approximately 15% said that they did not think about computers differently as a result of participation in the Sim-Stat unit, either positively or negatively, while approximately 3% responded with negative comments such as “It makes things more complex” (Survey, Latina female) and “I didn’t know how hard it is” (Survey, Latino male), meaning that a high level of difficulty was unwelcomed and associated with computer use.

Of the responses given by students who said that the use of AgentSheets did not make them think differently about computers, most comments were simply “It didn’t”, but a couple of students explained their thinking further. One student wrote, “Agent sheets didn’t really make me think differently about the computer. It just further showed me how the computer responds to the information that is put in” (Survey, White female). Another student accounted, "The agent sheets dont make me think diffrent [sic] of the computers you are just doing something more interesting with computers and not just play games all the time" (Survey, Latina female). Many of the students who commented that participation did not change the way they thought about computers already held positive views of technology and expressed high self-efficacy with computers.

Five main themes emerged from the 97 students who responded that they now thought differently about computers as a result of their participation in the Sim-Stat units using AgentSheets. Table 5.5 lists the themes, provides a brief description, and gives example responses to illustrate the theme.

**Table 5.5 Emerged Themes: Post-Survey Responses from Students who Reported Thinking Differently About Computers as a Result of Participation in Simulations in Statistics Units**

| Theme | Description | Example from Survey |
|---|---|---|
| Perceived Difficulty | Students now believed that computers are *not as hard* as they thought they were before. | "I didn't know that it was so easy to create simulations on a computer. I always thought that they were very complicated" (Survey, Native American male). |
| Ability to Create | Students can *create* simulations, not just use them | "I never knew that I could create such a well-done simulation :D Super Cool!" (Survey, Asian American female). |
| Expanded Uses | Students now saw that *computers have uses beyond what they typically did* on them (Facebook, music, watching videos, or playing games) | "I usually don't like using computers for anything but my entertainment but making a game is really entertaining to me." (Survey, Latina female). |
| Real-life Applicability | Computers can be used for *testing real-life situations* using simulations | "Now I know that you can use computer simulations to solve problems and you don't have to do the hole [sic] thing in real life." (Survey, White female). |
| Relation to Mathematics | Computers are *related to math* more than they originally thought | "Computers are related to math in more ways then [sic] I thought they would be." (Survey, Latina female). |

*Interview responses*

In his interview, Craig explained that he did not think differently about computers now. He said, “I’ve always loved computers. It’s pretty much all I do at my house, get on the computer and play video games. I just like it” (Interview #3). However, all other students (n=18) who were interviewed stated that they now thought differently about computers and their uses in some way. The interview responses also fell into the same themes as the online responses. Examples of student responses are listed below by theme.

Perceived Difficulty

- I didn’t know it would be in our reach to be able to make games like this. It was a pretty fun experience doing this, ‘cause I’ve always wanted to create a game on a computer. I go home and I play my video games and I see what they do and it’s pretty cool, and I want to be making games like that. (Interview #5).

Ability to Create

- I didn’t know that you could create your own game and publish it to the Internet till last year, and I thought it was just for fun, but it’s actually for education. (Interview #1).
- I never really knew that we could do stuff like this, make our own games, until we did it in sixth or seventh grade. That was really, really cool, when I learned that you can do things like that, creating worksheets, creating my own games. When I’m at home, I just use [the computer] to get on Facebook and play some games and that’s it. I do research on it sometimes, but not a lot of things like that where you create stuff. (Interview #17).

Expanded Uses

- I basically thought that computers were only used for Internet, and that you can't really do anything else. (Interview #15).
- It, like, showed me that there's more ways that people can do things on the computer instead of just Facebook and all that. If you wanted to do something fun, you could just get on AgentSheets and make something, and then, like, you could have people play it and show 'em, "I made this. This is what I did. (Interview #14).
- At first, I thought computers were all fun and games, and now I know that there's some things that could be, like, really challenging or things that aren't just Facebook or MySpace. (Interview #7).
- It helped me understand that there's many things to do with computers and how to work with them. [*What do you mostly do at home on the computer?*] Games or Facebook, or sometimes my mom needs to translate something, so I'll go to a translator so it's easier. (Interview #6).

Real-life Applicability

- I thought it made me think different because I found a different way that I could test things without looking up tons of different things first, I could just program it all onto here and then figure it out that way. (Interview #19).
- It made me think that you just don't go on Facebook and search things, like, pictures and all that, that you don't actually have to test in real life, you can just make one here and test it. (Interview #16).

Related to Mathematics

- I didn't know that we were gonna be able to use math. I thought we were just gonna simulate the properties and put it on a piece of paper and graph it from there. Probably there's gonna be a lot of math everywhere in most computers, and most computers have activities from math that can help you. (Interview #10).

Though there were responses in each of the themes from students who were interviewed and took the post-survey, the Expanded Uses theme had the most responses. Most of the students said that they had seen new purposes for computers, even if they also talked about other ways they had learned to think differently about computers.

**Using Technology to Assist with Mathematics Learning**

In the interviews, students were also asked "How did you like the statistics unit that used technology?" and "What do you think about the computer simulation activities?" All students were asked the latter question on the online post-survey.

The majority of the responses were positive both in the interviews and on the survey. In the interviews, students discussed enjoying the activities and preferring them to more of the same book and paper work. Pablo said, "Instead of workin' out of a book and lookin' at the board the whole entire time, it was more relaxing and easier. In regular class you have to do it out of books, and you have to listen to the teacher, so it kind of gets boring. But this, it made it easier, because while you're makin' a game, you're still learning your math" (Interview #14). Many students' responses reflected this same sentiment. Using simulations to help learn statistical tools made the lessons more interesting and easier to comprehend.

Some students felt that by using technology, they were able to better understand the related mathematics. Alfredo stated, "I knew there was this kind of technology, but I didn't know what it was called, and I thought it wasn't gonna help. It actually did help me [learn math]" (Interview #1). Cassandra also felt that using simulations in math class helped her learn the math content better. She said, "You learn more, because you're actually doing it on the computer instead of just getting it out of a book… I learn by seeing" (Interview #12). Maddie had an interesting comment. She said, "sometimes we'll go to the computer lab to take tests and stuff. But never really to do math. This was a different experience… I liked it a lot" (Interview #7). Even though the tests they went to take in the lab were math progress tests, Maddie did not consider this doing mathematics. There was something different about this experience for her that led her to consider this unit "doing math" whereas the other computer activities were not.

Veronica shared how by using technology during this unit she was able to go beyond simply completing the calculations and engage in more in-depth problem solving. In her words, "when you do it in class, you have to find your work by yourself" but in the lab "sometimes the computer can help you out … you had to still do things in your head and stuff, but it was, like, you did more" (Interview #2). Instead of focusing on computation alone as she does in class, she could consider the bigger picture, a larger problem. Alfredo appreciated the fact that the simulation was modeling something real, "It's not just a game, it actually shows what would happen if trees were together and one was on fire" (Interview #1). So the types of considerations the students attended to were not just solving a list of problems to find the list of corresponding right answers. They were engaged in a larger problem and using their tools of technology and statistics to help them generate solutions.

Damian appreciated the hands-on nature of the unit, "You can see the things, like the simulation, how it is, you got to create it and then you used it as math. That was really neat to me, how you made your own thing and then you used it to help you out with your research and stuff. I liked that" (Interview #18). The importance of ownership, of using your "own thing" to use for data collection became an important finding in this implementation as compared with the pilot study. In the pilot study, students programmed a basic simulation in one class period and did not use their own simulation to collect the data. They were then provided a pre-made simulation and used this to collect data. While this standardized the data collection process and made it run more smoothly, all benefits to engagement and ownership from using a student created simulation were lost.

Other students enjoyed the inclusion of technology in their math class simply for the fact that they like to use technology. Amy said, "I really like it. I'm a computer person" (Interview #15). Amanda agreed, "I like technology. It's almost like texting. I really like that" (Interview #16). While the reasons differed, most students gave positive feedback regarding the use of technology to help learn mathematics and the simulation activities used in their classes.

The majority of the responses to the question of how students liked the units and simulation related activities were positive on the survey as well. Approximately 80% of the students replied that the simulation activities were beneficial and enjoyable. Responses like "I think it was a fun way to learn and apply math to a game" (Survey, Latina female) were typical for this group of respondents. Students also commented on the how they appreciated the real world application of the unit and noted the power of simulating actual or potential events, making comments like:

- "I thought it was pretty cool that we could see real life situations on the computer!" (Survey, White female).

- "What I like about computer simulations is that you can base it off of anything. You could see if the dream you had the other night is able to happen, or if you could start your own tornado." (Survey, White female).
- "I think that the computer simulations are helpful because they can help someone to understand how one thing can affect another, and how every small thing put into a computer can make a difference." (Survey, White female).
- "I think that they are fun and could do a lot less damage than actually trying it in real life… they are very helpful and accurate" (Survey, Latina female).

Approximately 16% of the responses on the survey were neutral or mixed positive and negative with students typing things like, "Its o.k.", or "I think the computer simulations are fun, but it depends on the simulation" (Survey, Latina female), or "[The depictions] are fun to make but it is really hard to program everything" (Survey, Latino male). Having a mixed reaction to the unit was not uncommon. There were portions of the unit that were more straightforward and others that were more challenging. Factors such as a student's previous level of experience using computers in general, and more specifically AgentSheets, and their self-efficacy in both math and computers lead to different reactions to this challenge. Some were ready for the challenge, as it was in their zone of proximal development or ZPD (Vygotsky, 1978), while for others this was out of a comfortable learning zone. When this was the case, there were more mixed and negative responses.

There were a couple neutral and mixed positive and negative responses in the interviews as well. Adam stated, "I sort of like it and I sort of don't because sometimes being on the computer too long gives me headaches, and maybe it's not as fast as me just doing it on paper" (Interview #10). Kim thought the activities were fun but difficult, "Some of it was challenging… the behaviors were kind of hard to figure out without using the website." But she also said, "I liked it, 'cause I like using technology … I'm really good with the computer, so I can figure things out really quickly" (Interview #19). In this way the challenge of the project was acknowledged, but did not prevent Kim from enjoying the process and the feeling of accomplishment she had when she did solve the problems she encountered.

The remaining 4% of responses on the survey were negative with responses like "they get boaring [*sic*]" (Survey, White male), or "I didn't really understand much just that it depends on the probability" (Survey, Latina female). Lack of understanding seemed to be the most common underlying message in the negative responses, however one student commented, "I don't like it that much but I get it" (Survey, Asian American male), which seemed to be more related to interest than in understanding.

### Collaboration

The majority of students interviewed felt that peer-to-peer collaboration was a positive part of the experience and recommended keeping this as an integral part of future units. There were exceptions to this when the demands on the student became too great for him or her to finish her own project, when the partnership was chosen by the teacher and the students had much different work speeds and habits, or when the student preferred to work independently. Even within these exceptions, the students felt that enforced solo work would not be the right solution. Though they wanted to create their own individual projects, students valued the ability to discuss the project with peers and ask for and offer to help.

There were differences by gender in the responses to this question. Female students tended to express that they highly valued peer collaboration. Their responses were longer and more in-depth and elaborated on their experiences working with other students. Girls discussed how this interaction made the assignment more worthwhile and increased their persistence to complete it. Several girls described how wanting to help someone else was a motivating factor in learning the content first themselves.

Grace described her peer-to-peer collaboration experience in this way, “I worked with one person, a student in my class. She created her own and I created my own and we kind of helped each other with the behaviors and stuff. Like, if she had something wrong, I would help her, and if I had something wrong, she would help me. It was good; it was helpful” (Interview #17). Amanda stated that when she helped other students, “It was fun. It, like, felt like you knew what you were doing and that people appreciated you,” and that when she received help, “it felt like they knew what they were doing and that they were glad to help me” (Interview #16). Pablo said, “people would ask me for help and I’d help them, ‘cause I was already done … you’d just help each other out instead of just keeping to yourself, so it’s easier for everybody in the class” (Interview #14). The reciprocal nature of sharing what you know and asking for help when needed was a common thread through the responses about collaboration.

Most students enjoyed the interactions, but sometimes the need for help got overwhelming. Grace had a hard time balancing the demands of helping peers and completing her own work. She said, “I tried to help the person next to me, but it was hard, ‘cause I wasn’t doing it fast enough for this. I kept getting behind with setting her up… I wouldn’t always have enough time to help her, and she got mad sometimes” (Interview #17). Grace was aware of the increased demands her questions placed on her peers so when she asked a peer for help she said, “I usually tried to pick somebody who was already done or knew what they were doing … so they could just get me to the answer and we could both get back to our work, trying not to take up a lot of time” (Interview #17). Grace tried to minimize her questions and select students whom she felt had more availability to help because they were further along in the project.

For another student, Kim, helping people was part of her identity, “I like helping other people. I’ve been doing it since I was little, since I have a huge family” (Interview #19). Kim also felt that peers communicated in different ways with each other than they did in teacher-student interactions. Kim described it in this way, “Sometimes kids learn better from other kids instead of adults … other kids understand how to help you better, ‘cause they’re like you. Some of my friends, like, they weren’t getting what the teachers was saying, but when I went and helped them, they were like, ‘Oh, I get it now!’ Kids sometimes just have a better way of explaining it” (Interview #19). I asked her if providing assistance to others made it hard for her to get her work done and she replied that it did, but that she usually completed her work anyway because she had learned to work more quickly.

Male students tended to provide shorter responses to questions about collaboration. Several did not seem to place high value on the collaborative aspects of the lesson and some seemed displeased by the assigned partners and the expectation to work together. Quite a few of the boys said that they had not worked with anyone at all on the project, even though all students were assigned a partner. A couple students shared that they did not enjoy working collaboratively or that they preferred to get assistance directly from the classroom teacher. One student was frank about his feelings. When he was asked if he liked helping others in class, he hesitated slightly, but then said “No.” He later discussed how he got confused sometimes and was more often on the receiving end than on the giving end. Other boys also described how peer collaboration was one-sided, with some students specializing in helping others and others receiving help. Damian stated, “I would walk around and help them program, make sure everything was programmed correctly, make sure the ground wouldn't set on fire when the trees were supposed to, stuff like that" (Interview #18). This student explained that he had finished the project before he was even aware of the assigned partners, so he did not work with his assigned partner, but helped other students.

Teacher-created partnerships were a source of frustration for several students, both male and female. Several students expressed that there had been a mismatch between them and their partners. Alfredo said, "Most of the time he was just messing around, and I was trying to finish my work. So the last minute he finished, and I think he got his up [on the arcade]" (Interview #1). A couple of other students discussed how they finished before their partners and then were asked to help him or her complete the project. Other students expressed that they asked their partners for help, but that their partners had not known how to do it either, and they ended up having to ask the teacher for help.

Even though there were differences by gender, most students felt that peer-to-peer interactions were an important part of the learning experience for the unit. This was true even for students who were asked to give a large amount of time to helping others and for many of those who were assigned to partners who they felt were a mismatch to their working style. Several students described the benefits of peer-to-peer collaboration. Grace phrased it this way, "I think it's better to have people help each other, 'cause you can both figure out new things if you're working together than if you're working alone and you're lost. You've probably already done everything you can for yourself to figure it out, and then having somebody else to help you with it, it's highly likely [you'll] understand it better" (Interview #17). Working collaboratively was valued as an important part of the learning in the Sim-Stat units by most students. Although the conversation began within the confines of individual experiences, students offered opinions that spoke to a more generalized view of working collaboratively and the benefits of using online materials such as the wiki and tutorials to support this collaboration.

### *Wiki and Tutorial Use*

While there were no questions specific to tutorial and wiki use in the student interview protocol, several students made remarks about this topic in the course of answering other questions. Most felt that using the wiki and provided tutorials were beneficial to project completion and their understanding. They also mentioned appreciating the ability to work independently or with peers and not have to rely on the teacher as the only source of information. Grace stated, "I got to make it by myself. Like, *I* got to do it. I didn't really have any help. I had the Wiki and that's pretty much it. Nobody talked me through it. That was pretty neat." She went on to explain, "It was good to have it there, because then if you were ahead of people, then you could just go back to it and look at it. If you were behind people, you could still go look at it. It didn't matter which part you were at, it always was there and you could just use it whenever" (Interview #17). Not only did students prefer when the tutorial was available, but they were more engaged as evidenced by more on-task behavior, as we will see in Chapter 6 of this study. The vignettes in Chapter 6 highlight differences in initial emphasis on tutorial use between the two 8$^{th}$ grade teachers and the 7$^{th}$ grade teacher (who did not use the tutorial with students), and the observation logs show student engagement rates differing by teacher.

The availability of the tutorial and encouragement from the teacher to utilize it was quite different than the experience the students had in their 7$^{th}$ grade year. Students in Mr. Samson's class did not use the tutorial to help them with programming the virus simulation or the Frogger-style game. Instead, Mr. Samson provided mini direct-instruction lessons for the next steps in the program. Leo compared the experiences he had in each class like this, "It was, like, the same thing, but on the Internet it gave us the behaviors [this year], and in Mr. Samson's, we had to, like, make our behaviors. We copied the behaviors [this year], and [last year] we had to make 'em on our own" (Interview #8). Leo said that he preferred using the tutorial when programming behaviors because of the speed with which he could program; the tutorial made it was easier to complete the project, "I liked it when we got it off the Wiki 'cause we could copy it fast" (Interview #8). In this situation, it is important to understand that students cannot simply copy the code and reuse it in their simulations. To "copy"[9] the students must first read and understand the tutorial, then find the matching if-then statements in the conditions and actions pallets, select which rules to use, decide what parts need to be changed, and modify all the parts within the condition or action to make the rule work. It is quite a bit more complicated than simply copying-and-pasting a block of code.

Other students stated that, although they liked having the tutorial to get them started, they would like to make their own project even though it would not be supported by a pre-existing tutorial. Not having a tutorial was seen as OK once students had used the tutorials to learn the program for the first assignments. Some students mentioned being ready for the challenge of making their own project now that they felt they had a better understanding of how to use the AgentSheets software, so that a tutorial was not necessary. In this way, the

[9] The notion of "copying" can be disconcerting to many educators and parents alike who are more familiar with an environment where copying is likened to plagiarism and has negative connotations. This becomes a concern when presenting the program for approval to use within schools, especially during core-content instructional time, and not after-school clubs or electives. As we will examine in Appendix O, getting schools and districts to agree to participate in the program can be a challenge even when student engagement rates are greatly increased. In this age of high-stakes education, we must be cognizant of how we discuss programs that extend the core curriculum, and be aware of things that make the learning seem less legitimate, or less focused on student achievement (often a euphemism for student standardized test performance).

tutorials can be seen as scaffolding to competence in programming using the AgentSheets software.

**Agency and Ownership**

The Merriam-Webster Online Dictionary (2013) defines agency as “the capacity, condition, or state of acting or of exerting power.” This capacity to exert power, however, does not exist in a vacuum. There are many social structures in place (Bourdieu & Passeron, 1977; Harker, 1984) so in this study we will refer to agency as an individual’s ability to act independently within an existing social structure.

In many traditional mathematics classes students must give up agency to follow set procedures and ways of producing acceptable forms to demonstration of mathematical thinking (Boaler & Greeno, 2000). Furthermore, mathematics is often thought of as an activity to be completed individually; students are rarely encouraged to collaborate and may be actively discouraged from talking with others in class about mathematics as this is viewed as cheating. The mathematics learned is often in isolated chunks that are not explicitly related to any real application or use beyond the classroom. This practice has not been altered greatly for decades even with new curricula focusing on more collaborative, contextual practice. Many mathematics educators continue to teach in the way they were taught using isolated skills from textbooks, individual activity, and summative assessments marking the end of a student’s responsibility for understanding a particular content category.

The Simulation in Statistics units incorporating the AgentSheets software provided opportunities not usually found in traditional mathematics classes. As described previously, AgentSheets is an object-oriented authoring tool where users drag and drop portions of if-then statements to create computer programs games and simulations. An affordance of the

AgentSheets software was that students could avoid the steep learning curve of other computer languages such as Python or Java and can focus on the design and creation of their project at a high level. In this study, the AgentSheets software allowed students to retain agency by providing opportunities for them to make decisions about their mathematical learning. Students had choices about how to accomplish the task and used multiple strategies within the unit or even within a single class period. Resources including teachers, other students, and online wikis and tutorials, were used to assist students in creating a simulation of their own design. Students did not have to use preexisting depictions of characters or backgrounds in their simulations, but could design and draw agents using paint type utilities. Students could have also used preexisting images from the Internet or photos from the camera on their computers (if their computer had that functionality). Students began with a blank slate, and right from the start were making decisions about graphic design and layout, functionality, and data collection. Students commented about the ownership they felt by each creating their own unique simulation. Since students were able to utilize the simulation they just created to generate the data needed for the unit, students felt ownership not only of the simulation, but also of the data used to learn the related statistics. Statistical and mathematical tools were introduced as a way to make sense of *their* data to answer questions about the context of the simulation, not as a set of procedures to follow lockstep for a provided set of data. Self-efficacy beliefs and student interest were enhanced by the fact that students were able to use their own data to learn the statistical tools.

**Future Pursuits**

A natural extension of current interest and self-efficacy beliefs is relating those current feelings to future plans. In this study I was particularly interested in any college or career plans related to STEM fields. Students were asked about future plans at varying time intervals from the present: high school, college, careers, and any influence that participation in the AgentSheets unit may have on their interest in STEM careers. The responses to these questions were alarming. There seemed to be a substantial disconnect between what students listed as their careers of interest and their understanding of what schooling and coursework would be required for them to reach these goals.

**Careers of Interest**

There were a wide variety of careers students listed as what they would like to do when they were done with their schooling; everything from a tattoo artist to a doctor, sometimes from the same student. Amy stated, “I either want to be a doctor or a tattoo artist. I’m a really good drawer” (Interview #15). Pete stated that he either wanted to be a “lawyer or a UFC[10] fighter” (Interview #4). Other careers listed were: law enforcement, military service, professional athlete, pastry chef, ultrasound technician, art and photography, nursing, massage therapist, social worker, plastic or brain surgeon, veterinary medicine, acting, clothing designer, and teaching. A few students listed an interest in technology and computers including game design, with one student mentioning this as a back-up career to becoming a NFL (National Football League) player.

There was often a discrepancy between what the students listed as a career interest and their knowledge of what it would take to actually become a member of the given profession. For example, one girl, Erin (Interview #9), stated that she wanted to become a professional basketball player but she was not currently playing basketball and was not sure she would even try to join the high school basketball team. Another student, Veronica (Interview #2),

[10] UFC, or *Ultimate Fighting Championship,* is a mixed martial arts competitive fighting venue.

mentioned that she would need to take a math class in high school “not a hard math class, but a pretty average one” but she wanted to go to college to become a science or math teacher or an ultrasound technician. Damian (Interview #18) said that he wanted to be a brain surgeon but was unaware that he had to first have an undergraduate college degree before attending medical school.

Some students had a better understanding of schooling requirements, the majority of these students cited participation in programs such as RISE and AVID where they had been asked to consider career choices and pathways to entering their desired careers. In these programs, students were asked to look up higher education institutes that offered the programs they were interested in, related scholarships, and future job prospects in the given field.

**STEM Careers**

A few students had already identified that they were interested in STEM related careers. Veronica said that she wanted to be a math or science teacher and Juan and Craig were interested in game design. When students who had listed something else as a career choice were asked in particular about whether or not they were considering any STEM related careers, most students either said ‘no’ or explained how their chosen career used math and science.

A few students shared that they did not feel that they were particularly capable in these areas and this was the reason they were not interested in STEM related careers. Cassandra, who does not have access to a computer at home and does her research papers by looking up information on her phone, stated, “I’m not good at math, and when I use a computer I get confused. When a little screen pops up, I don’t know what to do. I don’t get what it’s saying. I’ll get confused” (Interview #12). Karmen explained that she was not interested in science because even though she liked it, “it’s just it’s a little too difficult for me” and as far as her interest in technology, “it depends on the job, like, if it looks really interesting” (Interview #11). The desire for a career that was fun came up fairly often.

Some students shared the concern that STEM careers wouldn’t be fun or interesting. Amy, who wanted to be either a doctor or a tattoo artist, said that she couldn’t “really think of anything that would sound fun” when asked if she were considering any STEM related careers. She went on, “I just don’t know any names of any math or science, except for, like, a scientist, that sounds fun” (Interview #15). She did not see being a doctor as being related to science.

While some, like Amy, did not see a career they were interested in as relating to STEM, others described how all careers depended on STEM knowledge to some extent. Pablo explained how he would use math and science in his career of interest by stating,

> [Law enforcement] does include science, because you’ve got to learn how to study the body, because if they get shot somewhere, you’ve got to know how to treat the person. And it does involve math, because in investigations, you learn how the bullet came, at what angle, at what time. Everything has math and science in it in some weird way. (Interview #14).

When asked if law enforcement used technology Pablo shared a conception and concern he had about technology. He said “I’m, like, athletic, and I want to stay in something that keeps me active... I don’t really want to sit in an office in a chair just doing a bunch of work on the computer.” Pablo, who plays on the basketball team, also mentioned that his favorite subject was science, but that a career in science didn’t really “fit me… I feel like it doesn’t represent who I am as a person.” He was more interested in a career with “action” as he put it (Interview #14).

Grace related how owning a bakery and being a pastry chef would involve math, "you'd have to know statistics, I think, business, stuff like that. Like, I didn't really notice how much you needed, like, to know in order to have a bakery until my mom told me, you have to work for someone, get a lot of money, have enough money to start everything. I was like, 'Geez, it's gonna take a long time', but it's worth it, 'cause that's what I really want to do" (Interview #17). Leo said that he would be interested in banking. He explained that banking "involves a lot of math, counting money and everything" and that "they do percentage in a lot of banks … I'm pretty good at percent and I thought a bank would be a good place to work for me" (Interview #8). It seemed that students had limited knowledge of possible STEM careers, and instead described how math, science, and technology were a part of their chosen career of interest.

It would be beneficial for students to have some understanding of what careers exist in STEM areas. If not, students are left with misconceptions and images presented on TV and other mass media of what STEM careers are and for whom they are "appropriate." It is unlikely that students will set a course for joining a career they have no knowledge of, or that they feel they cannot join because they have not seen individuals with similar characteristics to themselves in these careers. Career education for all students could be a place to begin to remedy this situation.

***Sim-Stat units' influence on interest in STEM careers***

Twelve of the nineteen students interviewed (approximately 63%) said that their participation in the Simulations in Statistics Units lead them to consider new careers or other aspects of their currently selected choice. Six of the interviewed students (approximately 32%) stated that because of their participation in the Sim-Stat units, they were considering careers using technology. For example, Karmen, who wanted to be an actress, felt that computers were easier to use than she initially thought they were and was now considering jobs in technology. This is how she described it, “I saw how fun it was and I was like, ‘Wow! This is really fun!’ I think I would do computers, ‘cause when I first didn’t do AgentSheets, I was like, ‘Oh, my God, I hate computers! I’m not doing that. I don’t like it, just get ‘em away. I don’t want to do that.’ But now that I’ve done this, I was like, ‘This is fun.’ I didn’t know computers could be like that. I figured out how good they were” (Interview #11).

Others shared this sentiment, if a little less dramatically. Amy also began to think of a career in technology that might be of interest to her. She said, “I don’t know why, but when we started this, I was thinking… you know how they have, like, hackers for the FBI that catch the bad people that were hacking? I was thinking that sounds fun” (Interview #15). Alfredo said that he started thinking about becoming a doctor during his participation in the Sim-Stat unit in the previous school year when students created a virus spread simulation. Lia said that she was now considering teaching in addition to becoming a social worker. She said, “I want to be a teacher like Mr. Banderas. I heard he goes to schools and helps them with this [AgentSheets]” (Interview #13). Maddie also thought that she would enjoy teaching students how to use AgentSheets, “I liked it a lot, and it’d be really fun to teach this to other kids and go to different schools and show them how to do this and help them learn about it” (Interview #7). Teaching was not a career she had expressed interest in before her participation in the Sim-Stat unit.

Some students who were interested in a career using computers, science, or math prior to participation in the Sim-Stat units said this experience reinforced their interest. Craig explained, “Oh, it made me want to do it more. It’s just fun” (Interview #3). Even though Juan did not have access to a computer at home, he said that he has always had an interest in technology. Because Juan does not have a computer where he can load a program, he was unable to take advantage of the offer to purchase the AgentSheets software at a reduced price for students.

For several other students, Sim-Stat unit participation did little to change their interest in STEM careers. Pablo said, “It didn’t, really. It was fun using it, but I didn’t want to change my mind about my career, ‘cause I’d already been looking at… law enforcement schools” (Interview #14). Likewise, Amanda said, “I’ve always wanted to be a photographer” (Interview #16) and that this experience did not influence her career choice.

Even if students were not interested in selecting a career in technology some expressed an enhanced interest in learning more about science and technology because of their participation in the Sim-Stat units. Grace said she realized that technology was not as hard as she initially thought it would be and that she was interested in finding out how it worked behind the scenes so to speak. She said,

> I didn’t understand the whole technology thing behind it. I want to learn about, like, how it works, how it knows, like, how it makes sense to the computer. I want to know… how computers [are] thinking. I want to know how they work… to see what technology is doing… like, “How is it even doing that?” I just recently had to take apart my iPod, and it was neat seeing all the stuff, but I want to know what each thing does. (Interview #17).

Though she did not see computers as her future career path, her interest in technology was enhanced by participation in the Sim-Stat units. In this study we examine interest and shifts in interest states. There is evidence that participation in the Simulation in Statistics units increased interest in technology for some students.

**High School Courses Needed for Career Goals**

Students in the AVID program were scheduled to look at the class offerings at the high school to try to figure out what to register for. Not all students were eligible to participate in AVID – they had to be first generation to go to college in their family, among other requirements.

Students not in the AVID and RISE programs, and even some students in these programs, had very little understanding of what courses were offered at the high school. This included required and elective credits for graduation and college entrance requirements. Grace said,

> I don't even know anything about the classes or anything. Nobody really ever talked to me about classes, the kind of classes I need to take. One of the things that I'm worried about going to high school is being on my own, having to decide what I want to do, what classes to take. And I'm not sure, I'm in AVID, so she talks about stuff like AP classes, but I don't really know anything about 'em, like everybody else does. So I'm kind of worried that I might get lost. (Interview #17).

These students were in $8^{th}$ grade and only had a few months left in middle school. There is one high school in this community and it is a 1-minute walk from the middle school, yet when asked what classes they would need to take at the high school for their chosen careers several students responded that they had no idea what was even offered at the high school. Others said that they would study something directly related to their stated career of choice whether or not this is likely to be offered at the high school level. For example, Damian, who wanted to be a brain surgeon, said, “I’ll probably have to study a lot in science, maybe do a little bit in health, study the body, have to look at the brain a whole bunch” (Interview #18), though there are very few anatomy and physiology courses offered at the high school level and none at the particular high school this student would most likely attend. This made me wonder how students were supposed to get the information they clearly needed to make course selection choices in high school. Perhaps the counseling services at the high school would be helpful to this end. It may be that there are limited decisions about coursework at the freshman level anyway and that by their sophomore year, students would be able to choose classes to help them prepare for careers in which they are interested.

Other students listed classes that were likely to be offered and then explained why these would be helpful for their chosen career. For example, Pablo (Interview #14) who wanted to go into law enforcement said that he would have to take classes in, “The study of the body, I don’t know what it’s really called, for science. I’ll have to learn how to take geometry, probably, because you’re gonna have to see the angles of the way what he was shooting. A lot of PE,” because police officers have to be in good physical condition. Amanda, who wanted to be a photographer, said she would take Spanish, math, and reading classes in addition to photography classes. She provided reasons for taking each of the classes that were related to being a professional photographer. When traveling to take photographs, for example, Spanish is important because she wanted “to be able to talk to the people there”, math is useful for calculating “how much it’s gonna cost, how far you need to go, how much time it’s gonna take”, and reading skills are valuable because “you need to read signs and tour guide packettype things" (Interview #16). For Amanda, all coursework was directly applicable to her career choice of becoming a professional photographer.

For Erin, who listed professional basketball as one of her careers of interest, stated that her high school courses would depend on the career she ended up picking. She said she would "probably take more math classes if I want to be a teacher, art classes if I want to be an artist, and probably, like, more PE classes if I want to be in basketball" (Interview #9). Since she was undecided about her chosen career, she did not have specific courses selected for high school. What was missing from several of these discussions was knowledge of a college preparatory course of study to allow them the best chances of being accepted into the university or college of their choice.

Most students listed that they would enroll in high school courses in math, science, and Spanish, and 5 of the 19 (26%) interviewed said they would take computer classes, if offered. One student, Juan, who was interested in becoming an NFL player with game design as a back-up career, qualified his interest in taking computer classes by saying that he would only take computer classes if they had some that didn't make him stare at a computer and make his eyes hurt. He phrased it this way, "[I would take] lots of math classes, obviously, 'cause this stuff, building games, has a lot to do with math. Some computer classes, [pause] I don't know if they just have classes where you have to stare at a computer, [pause] so your eyes don't hurt" (Interview #5). This was the second time Juan mentioned his eyes hurting in our interview. I wondered about glasses for Juan. It would be a shame if a need for prescription glasses prevented Juan from pursuing an interest and aptitude for computer science.

**College Plans**

All but one student said that they would be attending college. Most students, however, did not know what they would study and were not aware of the requirements for application and acceptance into college. For example, a couple of students said that they would study medicine, but they did not seem to understand that an undergraduate degree would be required before attending medical school or the level of commitment admittance to medical school would entail. Amy explained that she would study "science to be a doctor, just in case I don't want to be a tattoo artist anymore" (Interview #15). Other students had an idea of what they would study, though they had no concrete plans. Erin said, "I might study art, like, say, Da Vinci. I don't know who painted the Mona Lisa. I want to know more about the history of art, who was the first person to create art, who found out art. And if I wanted to be a basketball player, I could learn about the basketball players, like Michael Jordan and all those other people" (Interview #9). Veronica said that she would study two things, "ultrasound technician and teaching. Maybe it'd take those two, just in case, like, one didn't work out, I'd take another" (Interview #2). Karmen also had an idea of what she wanted to study. She said she would go to college even though she wanted to become an actress. She said, "If I'm doing actressing [*sic*], I would just, like, go to actress—like, just do all kinds of stuff for actressing [*sic*]. Math, I would study mostly everything in math, and for computers I would, like, take computer classes, too" (Interview #11). Only a few students had a clear vision of what they would like to study or the implications of this choice. Kim and Grace were members of this small group.

Kim shared a detailed description of her future college plans, "I'm gonna go to CSU to their vet program. So maybe if I get into their vet program right away, I only have to go to college for four years instead of eight. 'Cause I don't want to go into the regular college first and go for four years and then go to vet school and go for another four years. If I have to do that, I'm gonna do the summer classes, too, so I can get done in two years" (Interview #19). Grace also had a clear vision of her future schooling, "I'm gonna try to go to Johnson & Wales, because they have a really good culinary arts school. 'Cause my aunt's friend just graduated not that long ago, and she's really good. She would post pictures on Facebook of her things that she had made in school, and they were really neat things, things that I can see myself doing. Like, I want to do that. I want to have something. It's like a work of art, but you can eat it!" (Interview #17). Both Kim and Grace had family members who provided information about the specifics of their career choices. In a large part due to this information from home, Kim and Grace had specific plans while many students were still undecided.

It is not uncommon for middle school students to be undecided on career plans; they have several years before they have to decide. However, there did seem to be a lack of knowledge about careers in general, and STEM related careers in particular. It was not just that they did not know which career they would pick, but that they lacked information about the range of possibilities, and what picking a particular career meant for future schooling requirements. It was surprising to me how little many students knew about the process of schooling, and alarming that as 8$^{th}$ grade students they would be attending high school in a few months time, but many did not know what classes they needed to take in high school, or even what was offered at the high school level.

The challenge then, is to not only provide opportunities for engagement and transitioning interest in technology, but to pair this with information about how to take this interest further into future schooling and STEM related careers. Participation in the Sim-Stat units showed increased engagement and shifting interest states, and most (approximately 63%) of the students who were interviewed related that the experience had lead them to consider new careers or alternate aspects of careers already of interest. About one-third of the students interviewed said that as a result of participation in these units, they were now considering careers using technology. It would be ideal to interest an even greater number of students in STEM careers, given the likelihood that a certain percentage of these students will eventually choose careers unrelated to STEM areas. In future intervention development, the inclusion of career education as a part of the unit may be one way to begin to address this goal.

**Summary**

In this chapter we looked at student interview responses and responses to open-ended survey items to address research question RQ1 (What are students' current levels of interest and self-efficacy in technology and mathematics?), sub question RQ1.1 (In what ways does interest development differ for students with repeated experiences using the AgentSheets software?), Claim 1 (The intervention we developed and implemented helps transition students' interest levels in technology and mathematics from triggered to maintained situational interest over time) and portions of Claim 2 (Students' social addresses are not good indicators of their interest level).

Overall the qualitative data examined in this chapter showed that the majority of students had high levels of interest in both technology and mathematics, though reported interest in mathematics was slightly lower. Students also expressed relatively high levels of confidence and self-efficacy with computers and mathematics. This was true for both male and female students, though Latino/a students expressed lower self-efficacy in both computer use and mathematics than white students. There was a wider gap in self-efficacy beliefs between

Latino/a and white students in mathematics than in computer use. This supports Claim 2, that students' social addresses are not good indicators of their interest level, though social addresses do seem to influence self-efficacy beliefs in mathematics and to a lesser extent computer use.

There was also evidence to support Claim 1, since several students described experiences that demonstrated interest transitioning from a triggered interest state to a maintained situational interest state. This seemed to correlate with repeated exposure to the Sim-Stats units using AgentSheets to program simulations and games. Students with repeated exposure were more likely to show evidence of transitioning from triggered to maintained interest states. This could be, in part, due to how the term "maintained interest" is defined; maintained interest involves interest over an extended period of time or interest that *reoccurs* and again persists.

Even among students who had repeated exposure to the units, as with those considered AgentSheets Novices, there was a relatively low interest in STEM related careers on average. Though for some students, having the opportunity to engage in the Sim-Stat units over multiple years translated into an emerging individual interest and interest in pursing a career in technology or mathematics.

Analysis of interview responses also exposed that many students had a lack of knowledge of career possibilities, especially STEM related careers, and the schooling requirements for the careers that they were aware of, such as becoming a doctor or lawyer. Many students did not know what high school courses were available, even though they would be enrolling in high school in a few months. Many of these students also seemed unaware of which high school courses were required for college admittance and/or would help them prepare for the careers they stated as of interest.

Based on these findings, it seems imperative that we must prepare middle school students to understand what they will need to take in high school to move them in the direction of their preferred careers.  And we must ensure that STEM related coursework and other opportunities exist at the high school level for those interested.  This is especially true for computer science and engineering, as math and science opportunities are typically available in current K-12 curriculum.

The next chapter examines the results from the observation logs and the video and audiotapes of the class sessions for each of the teachers.  Chapter 6 will address Research Question 2, engagement and participant positions, and the remaining parts of Claim 2, social addresses in relation to engagement and participation.  Student projects will be reviewed to evaluate the degree to which students were successful in project completion and extension.

**Chapter 6. Student Engagement and Participation.**

The Merriam-Webster online dictionary (2012b) defines the noun *engagement* as emotional involvement or commitment, and the transitive verb to *engage* as to hold the attention of, or to induce to participate. In this study, we will conceptualize engagement as having two parts; first, engagement has an affective component, sparking and sustaining individuals attention and interest, and second there is a behavioral component to engagement, individuals participating and expending effort in working on the task at hand (Barron, 2010; Marks, 2000). In this definition, participation is an integral part of engagement.

Staying in a state of engagement requires that the task be appropriately challenging and accessible. To hold individuals' attention, it must be easy enough to enter the task and induce participation, but complex enough to continue to provide adequate challenge as the individual becomes more skilled. This sweet-spot is called the "Flow Channel" by Csikszentmihalyi (1990, 2008). This is the area between boredom and anxiety as the task becomes increasingly challenging. For Gresalfi & Barab (2011), engagement is not attributable to student interest or the task / environment alone, but rather "the result of the interaction between the two" (p. 302). Gresalfi & Barab (2011) examine four different forms of engagement: procedural, conceptual, consequential, and critical. Procedural and conceptual engagement are considered to be content focused, whereas consequential and critical engagement are related to student decision making in context. All four forms of engagement were observed in this study. Observations of behavioral participation can be used as a proxy to understanding whether or not an individual is engaged.

In this study, each classroom was video recorded in the computer lab during unit implementation. Two video cameras, complete with boom microphones to capture audio, recorded high definition digital video of approximately 100 hours of classroom interactions and direct instruction segments. These video recordings are housed on seventeen 16-gigabyte memory cards, for a total of approximately 270 gigabytes. Both teachers, myself as the researcher, and the undergraduate student assistant from the University of Colorado Boulder, wore lapel microphones connected to digital audio recorders. These devices recorded over 200 hours of digital audio of classroom interactions.

In addition to the audio and video recordings of each class, I conducted point-in-time observations of student participation and recorded these in observation logs. I recorded three spot checks of participation per day, per class period, for each student, in both computer labs, for a total of over 2,500 points of data on student participation and engagement.

In this chapter observation logs, video and audio recordings are used to address the following research questions and support the following claim:

RQ 2: How does the implementation of technology-enhanced mathematics instructional units affect students' engagement?
- 2.1 In what ways does engagement differ by gender?
- 2.2 What participant positions are available to students throughout the AgentSheets units?
- 2.3 How do students take up the available participant positions?

Claim 2: Students' social addresses are not good indicators of their level of engagement, interest, and participation in these activities. Though the kind of engagement and participation may vary by social address.

This study addresses these research questions by examining engagement in four ways. First, engagement is examined at a global level through participation logs for all students in all classes, and second, at an individual level through videotape analysis to create vignettes of six focal participants. Third, this study examines if and how student interactions and participant positions (available and taken up) in the computer labs can work to disrupt asymmetric access to assistance and lead to high engagement for a large percentage of students. And fourth, the author evaluates students' uploaded projects to verify project completion and functionality and to explore if and how engagement rates influenced project completion and extension.

Engagement in learning involves both affective and behavioral components (Marks, 2000). In the computer lab, engagement is visible by monitoring what students are doing during individual work time and during the teacher presentations. Operationalizing engagement to be able to recognize and document when it occurs is essential for studying classroom settings. For example, when students are collaborating, extending each other's thinking, and sharing excitement over programming a simulation, they are seen as highly engaged in the material. Another example of high engagement is student assisting behavior where certain students self-select into "islands of expertise" (Barron, 2010) and offer guidance to others in class. In this study, these behaviors would be coded as collaborative engagement and taking up a high self-efficacy with computers or mathematics participant positions. Evidence of disengagement would be behaviors such as surfing the web or other computer activities unrelated to the unit, or not using the computer at all (talking to friends, reading a book, doing homework from another class, etc.). In this study, these behaviors would be coded as off-task engagement and perhaps taking up a low self-efficacy with computers or mathematics participant position (depending upon the particular circumstance).

For the analysis in this section, I used a combination of methods to provide both a larger perspective and an individual participant level of detail. To gain perspective and understanding of the participation and engagement of the entire group of participants, I used statistical analysis to quantify the observation logs. To complement this method, I used a narrative description approach (Derry et al., 2010) for the videotape analysis to create vignettes of focal participants. A narrative approach is useful because quantification alone does not provide details about how the classroom interactions unfold across time and the complexity of these interactions.

**Focal Participants**

Focal participants for the observations were selected using similar criteria to that used for selecting interview participants. I tried to balance gender, race, and previous AgentSheets experience to create a sample that was similar to the population of the 8th grade in NMS. I also ensured that both Ms. Avery's and Mr. Connor's classes were represented and that some students from each class had taken Mr. Samson's remedial math classes for 7th grade mathematics.

Six students were selected with the following characteristics:

- 3 males, 3 females
- 4 Latino/a students, 2 white students
- 3 students from each teacher (Ms. Avery and Mr. Connor)
- 3 students with AgentSheets experience in 7th grade
- 1 student received special education support services

Table 6.1 lists the participants and the characteristics considered for selection.

**Table 6.1 Focal Participants' Characteristics**

| | Damian | Grace | Grant | Kim | Lia | Pablo |
|---|---|---|---|---|---|---|
| Gender | Male | Female | Male | Female | Female | Male |
| Race | Latino | Latina | White | White | Latina | Latino |
| Teacher | Ms. Avery | Mr. Connor | Ms. Avery | Ms. Avery | Mr. Connor | Mr. Connor |
| AgentSheets Experience | AS Expert | AS Expert | AS Expert | AS Novice | AS Novice | AS Expert* |
| Previous Math Level | Grade Level | Grade Level | Grade Level | Advanced | Grade Level | Advanced |

* Pablo had taken an elective class using AgentSheets for game design and should be considered an AgentSheets "Expert", though he did not participate in the Sim-Stat units in 7th grade

While viewing the videotapes of the classes during the Sim-Stat unit, I paid particular attention to the focal participants. I also examined the projects each uploaded to the arcade. The analysis of the videotapes and uploaded simulations is presented below.

**Videotape Analysis**

I used a narrative description approach to the videotape analysis. To create the vignettes below, first I watched and coded the entire video, paying special attention to focal participants. This coding was also completed by my colleague and was used to verify inter-rater agreement. (See Chapter 3.) I then recorded what each focal participant was doing throughout each class period, each day, during the first week in the lab (the duration of the Sim-Stat unit). Finally, based on these notes, I wrote a summary vignette for each focal participant, returning to certain video segments as needed for clarity. For each focal student who uploaded his or her forest fire simulation, a screen shot is included in the corresponding vignette. (See Figures 6.1, 6.2, 6.4, 6.6 and 6.7). Grant did not upload his simulation and therefore a screen shot is not included in his vignette. Screen-shots provide a visual image of what each student had completed and was describing in their interview. Further analysis of these simulations is discussed in the *Student Projects* section of this chapter. Lia's and Grace's vignettes are combined below because their stories share some similarities. Both of their experiences speak to the fact that for many students, peer collaboration was an integral part of their experience with the Simulations in Statistics Units.

***Lia and Grace***

Collaboration was an important part of the Sim-Stat experience for both Lia and Grace. I coded instances of this behavior as working collaboratively with one or more peers (E2.C) and providing support for others in technology (A3.ST). See Appendix L for the codebook used for qualitative data coding. Lia and Grace seemed to enjoy sharing their knowledge and helping others. Lia was very verbal, talking aloud as she problem-solved. Sometimes this was directed toward another student in the form of help or asking a question, but at other times she was just narrating her learning and thoughts.

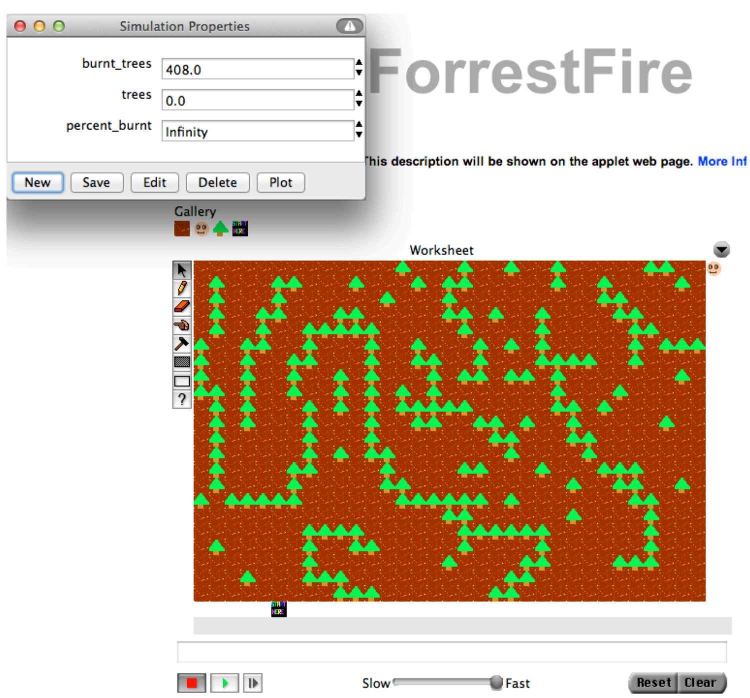
Lia talked through the pre-survey stating and answering each question aloud. She took longer to complete the pre-survey than many others in class (12 minutes versus 8-9 minutes) as she thoughtfully processed each question. Not only did she answer the questions aloud, she often discussed the interpretation with the girl on her right. At one point, she said, “What? I’m being honest!” when her response of “strongly disagree” to the question “I understand what is going on in math class” drew laughter from both her and the girl to her right. As she worked through the survey, she explained what each of the answer choices meant (courses taken before such as Microsoft Power Point, game design, etc.) to the girl to her right. She did this in a mixture of Spanish and English, engaging in code switching. The two girls also had a discussion surrounding the question “I want to study computers in college.” They talked for a couple of minutes about going to college and what they would like to study. Again this was in a mixture of Spanish and English.

Lia would focus for a time on the task at hand and then would take a mental break by talking about an unrelated topic. For example, while taking the survey, in which she seemed highly engaged, she talked about how strong she was, flexing her bicep and laughing while the girl next to her poked at her arm. The two girls also had a side conversation about speaking Spanish. The girl next to Lia said that she only speaks Spanish to her Mom and Grandma. Lia said that she spoke it much more often.

During the direct instruction portions of the class, Lia sat near the front and seemed focused on what was being presented. She responded in a way that demonstrated that she was listening. She also asked questions and volunteered to participate as needed. For example, when Mr. Conner was teaching the game design unit Lia volunteered to play the game that Mr. Conner developed in AgentSheets as it was projected for the class to see.

Lia also exhibited behavior that indicated that she liked to get information directly from the teacher. She often had her hand in the air requesting help. Mr. Conner would come by to help. He would answer her initial question and then move on to the next student, not spending too much time with any one student. Several times Lia would have her hand back up in the air before Mr. Conner had gone very far at all. Mr. Conner did not always make it back quickly to address Lia's follow up questions. Occasionally, Lia would have her hand in the air for 5 full minutes before giving up or getting help.

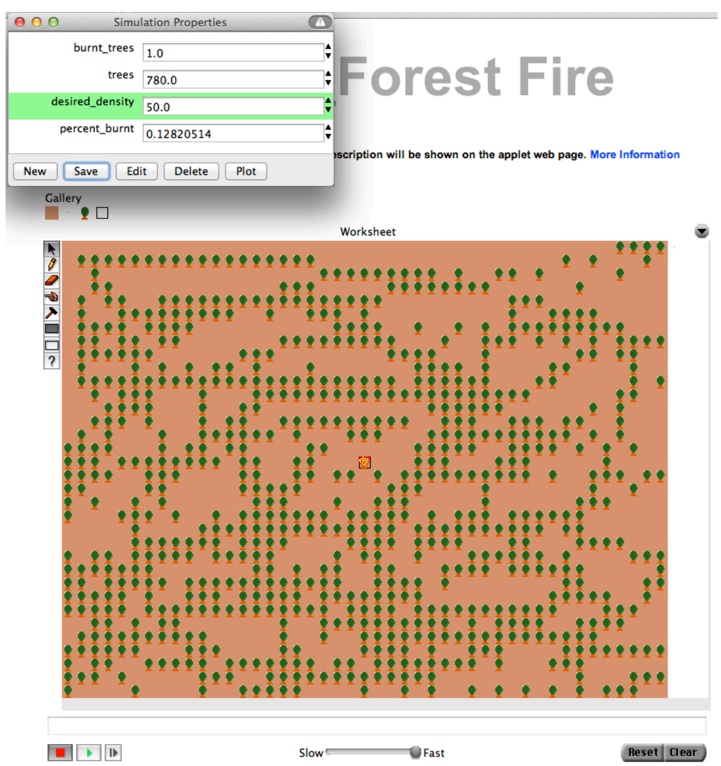
**Figure 6.1 Lia's Forest Fire Simulation**



When Lia learned something, she would share this knowledge with others. For example, the registration key for the AgentSheets software had to be entered daily on certain computers in the lab. One of these computers was Lia's. Once she learned where the file containing the key was and how to enter it into the log in screen, Lia walked around the lab helping students log into AgentSheets. She continued this practice each day the class was in the lab. Even when Lia began to fall behind in getting her own project done, she would take time to help others keep up with her.

Grace also spent a large portion of her time in the lab helping others. She focused on helping one girl in particular, a girl with a visible cleft lip and some behavioral issues in class. As you may recall from her interview in Chapter 5, Grace discussed her experiences with collaboration and expressed some frustration at the demands of the constant needs of her friend.

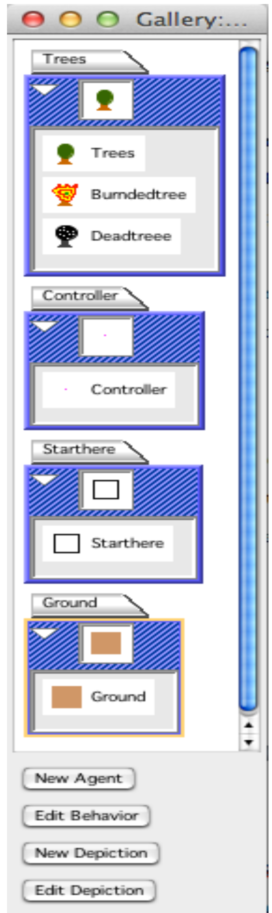
**Figure 6.2 Grace's Forest Fire Simulation**



Through classroom observations, it became apparent how the helping arrangement Grace was in with this student could be overwhelming. Grace was always by her side and tried to help her with all aspects of the project and other mathematics coursework. The girl was an almost constant distraction as Grace tried to work on the computer or listen to the direct instruction portions of the unit. At one point, I observed the girl grab Grace's hand and bend Grace's fingers back until the knuckles popped. Grace flinched in pain, but did not stop the girl's actions. At another point, the girl was pulling on Grace's hair when they sat side by side as the teacher was presenting the next steps to project completion. At initial glance, it looked like they were both off task throughout the classes. In actuality, Grace was trying to calm this girl's behavior and teach her how to do the project, while simultaneously attempting to complete her own work. It is not surprising that Grace expressed some frustration at the demands of this situation.

Both Grace and Lia progressed more slowly through the project as a result of their providing assistance to other students, although this was not the case for all students who collaborated on the project, especially if that help was more reciprocal in nature. By the second day in class, there were major discrepancies between the progress toward project completion by Lia and the girls next to her made compared with others in the class. For example, by the end of day two of the unit, three hours into the project, the girls had just finished drawing their tree and ground agents and had no programming of behaviors done at all. See Figure 6.3.

**Figure 6.3 Depictions of Agents**




Others in the class had completed programming the behavior for the trees that helped set up the fire burning and spreading properties of the simulation.

Lia exhibited off-task behavior fairly frequently, but for relatively short periods of time. When she was off-task, she often distracted the girls next to her, and vice versa. This likely explains the slower pace at which these girls completed the project. These girls also relied on getting help almost exclusively from their teacher, Mr. Connor. This was the way the class was set up. Students were only shown the wiki quickly in passing and not given specific directions, such as displaying the web address on the board, to access it from their computers. Lia and Grace might have benefited from access to the tutorial earlier in the unit. Perhaps introducing the wiki earlier and showing students how to utilize it as a tool for answering one's questions might have helped alleviate the situation of Lia having her hand up in the air for up to 5 full minutes and could have provided a way for Grace to find the next steps to project completion that she could not attend to during the direct instruction portions.

***Kim***

Kim's vignette provides an in-depth example of a student with high self-efficacy in computers and mathematics and high collaboration with others. Unlike for Lia and Grace, this collaboration did not put Kim behind in project completion, though she did choose to complete some work at home so that she could devote more in class time to assisting her peers.

Kim was a white female student in $8^{th}$ grade. In her interview, she said that she liked computers and math, though she had no previous experience with AgentSheets prior to this unit. Kim liked to work with other students and as soon as she figured out the next steps to project completion, she quickly shared this with students in the class. A natural teacher, she quickly moved from novice to expert among her peers. Even those students who had used AgentSheets before turned to Kim for help.

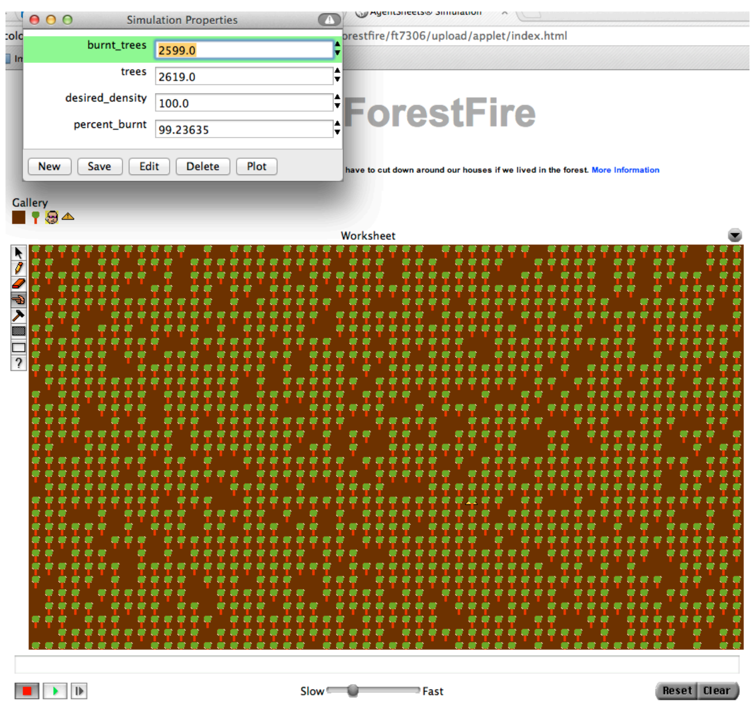
Kim focused her attention on those who were the furthest behind. In particular, she worked quite a bit with a special needs student, Grant. (See Grant's vignette below). From my observation notes:

> The boy she helps is very easily distracted, perhaps ADHD. He asks the teacher "Do I have to do a survey?" Teacher nods. "Does it have to be right?" The teacher nods again. He has a hard time focusing on the screen. He asks, "Can I play games?" Teacher tells him to finish. Grant has a constant chorus of "Miss. Miss. Miss. Miss." He would try anyone's patience. Kim takes this student on

– likely the most difficult and needy student in the class. (Observation Notes, November 8, 2011).

Kim watched and participated in the whole group presentations for the most part, though she would often say the answers under her breath. I got the sense that she was still trying to find her group of friends. She sat by a couple of different pairs of girls but always seemed to be outside the pair, the third wheel.

**Figure 6.4 Kim's Forest Fire Simulation**

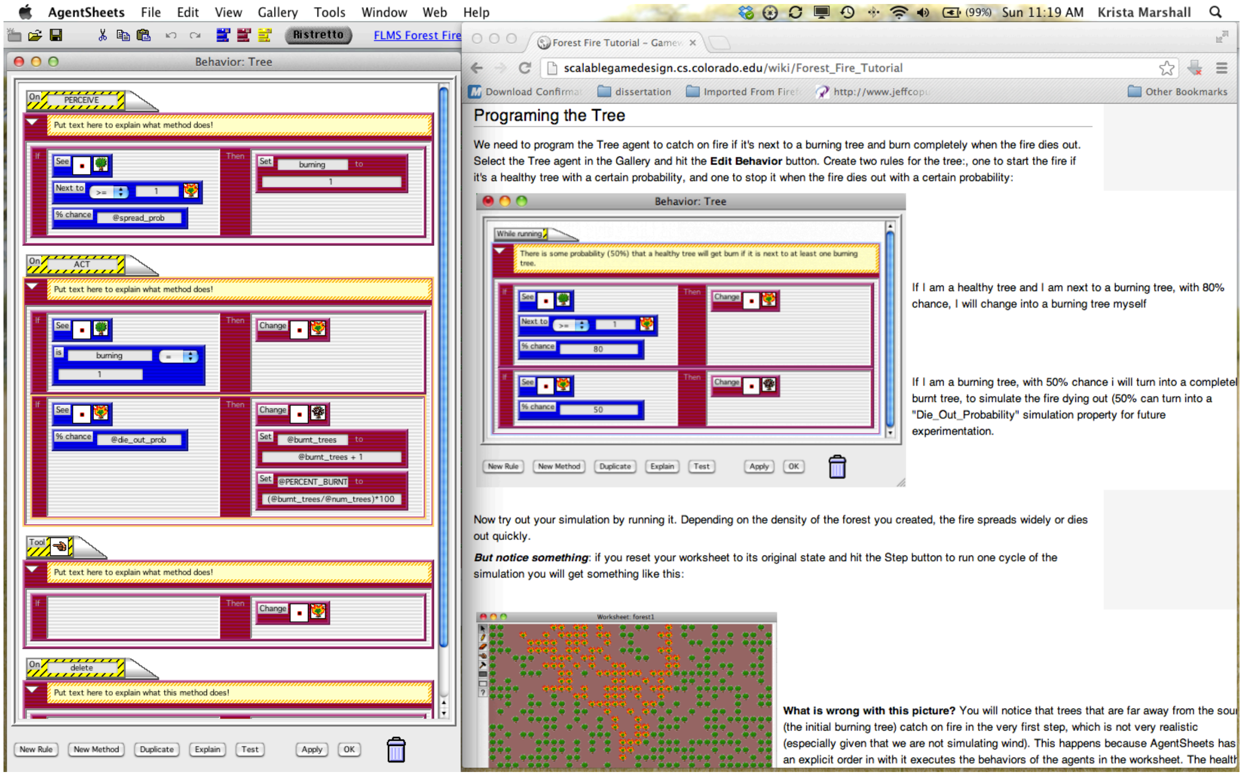



The girls she picked seemed like those who were not academically focused. They often talked through the presentations and needed frequent help from teachers in the lab. Sometimes they would go back to the lab right after a set of direct instructions and raise their hands and ask, "What are we supposed to do?" Ms. Avery expressed frustration and embarrassment with this. At one point she said, "Several of you are asking what to do, and Ms. Marshall just spent the last 20 minutes telling you what to do next." Ms. Avery seemed to be exasperated by the fact that these girls were more interested in the social interactions going on during the instruction than the content itself.

Kim's behavior was quite dissimilar to the girls she occasionally sat next to. Kim paid attention during the presentations and was able to jump right into her project after a direct instruction section. She figured out things quickly and by the third day of the unit began to circulate throughout the class helping students with their projects. Kim tended to take the mouse from the person she was helping and do the task for them. Some coaching on how to help peers, such as not taking the mouse (and therefore the control) from the person you are helping, would have been good at the beginning of the unit. This was especially true for students in Ms. Avery's class, as she encouraged peer-to-peer assistance. Not taking the mouse and other ways to assist students with their projects were emphasized at the summer institute for teachers, but this message did not get to students for helping peers.

Kim asked for help from adults in the lab when needed. She worked with all the adults in the lab, but she did not ask her peers for help. The time spent helping Kim with a problem or next steps was particularly well spent as she then shared this with several students she was helping. Kim spent a significant portion of each class period assisting other students. For example, in the third class Kim spent about 50 minutes of the 80-minute class period helping other students! This, in essence, created another "teacher" to help in Lab 1, allowing teachers more time with each person being helped. By the fifth day in the unit, Kim was even helping in the other lab. She often used the same techniques the teachers had used with her. For example, I showed her how to place the tutorial window side-by-side with her behavior window. (See Figure 6.5.) I then saw her showing this to several students in the lab.

**Figure 6.5 Behavior Window with Tutorial Side-by-side**




Students sought out Kim. As a result, she had a hard time completing all portions of the project in class. She completed the parts that required her to be in the computer lab quickly. For example, she only spent about 15 minutes to run her simulation to collect all the required data. She entered this into the Excel spreadsheet as she went. Once this was done, she asked for, and received, permission to do her data analysis (finding the mean, plotting points, drawing line of best fit, etc.) at home because she wanted to continue to help people in the lab.

At a couple of points in the unit, Ms. Avery and Kim were working together to problem solve around an issue or debug another student's program. There seemed to be a hierarchy of helpers in the class. Kim would try it first. If she couldn't figure it out, she would ask Ms. Avery. If Ms. Avery was stumped, she would ask Kathy (the college student helper) or myself.

Kim's willingness to help other students debug and problem solve demonstrates her interest in both collaboration and problem solving. She would rather help others debug their work than attend to her own, and she maximizes the opportunity to do so. Kim took on an expert participant position in the class, one that was quite similar to the role of the teacher.

***Grant***

Grant's vignette illustrates the low threshold of the project that allowed for access for all students. His story also highlights the demands this type of unit can place on teachers and the benefits of encouraging students to work together and access resources independently.

Grant was a white male high-functioning special needs student in $8^{th}$ grade. Grant was about 4'5", and was of slight build with a shock of bright blonde hair. Grant dressed up on basketball team days; he wore a dress shirt and tie. While he was released from class with the basketball team, I do not know if he played on the team or was a supporting member. I have no information on his particular needs, but he had a very difficult time focusing on any task. There was one notable exception to this. In one class period on the fourth day of the unit, Grant worked independently for approximately 12 minutes. In all other observed cases Grant stayed focused on a task for at most 1-2 minutes at a time.

He had previous experience with AgentSheets because he was in the lower $7^{th}$ grade math class. Grant did have some knowledge of AgentSheets from using it before. I observed that he remembered how to import an image from Google for an agent depiction and spent time doing this. His memory seemed spotty though, and he required quite a lot of support from teachers and fellow students during the unit. He was able to complete the simulation with help, though he did not upload his simulation to the Scalable Game Design Arcade.

At first Grant would only ask for help from his teacher, Ms. Avery. He would follow her around the lab saying, “Miss! Miss! Miss! Miss!” even when she was presenting to the whole class. When it got particularly bad, like when she couldn’t finish a sentence to provide directions to the rest of the class, Ms. Avery would say something like, “Shhhh… Grant you are not helping me, I’ll come over to you in a minute.” Ms. Avery devoted much time to providing one-on-one directions to Grant. She would get him going and then turn to try to help another student and he would often almost immediately begin with “Miss! Miss! Miss! Miss!” and follow her wherever she went in the computer lab. He did not ask for help from the college student helping in the lab or me. After a couple of days, a fellow student, Kim, began to help Grant. From that point forward, Grant would ask either Kim or Ms. Avery for help. Once in a while he would ask the male student sitting next to him, but these interactions were usually short.

When Grant did not get help right away he would walk around the class touching things, picking up cords, stretching up to grab signs hanging in the lab, leaning over other students, standing behind students looking at their computer screens, adjusting monitors, picking up chairs and putting them over his head, or pushing his chair back and forth while standing next to it banging his chair into the table. If he were sitting in his chair, he would rock his body back and forth, throw his head back, swing his feet vigorously, or pound his head and fists on the table. When this happened, the boy next to him would reach out and gently press his hands over Grant’s to keep him from shaking the whole table. Grant would usually stop and move on to something else. At one point, Grant had managed to pull his monitor off its base and Kim got up and helped him put it back together. It took them a couple of minutes to reassemble the monitor.

I thought that Grant would try other students' patience more, but I saw no outward signs of frustration. The students didn't seem bothered by him. In fact, some students in the class seemed to look out for Grant. For example one day, Grant asked Ms. Avery how to log out of the computer, but left before doing so. A male student on the end of the same row stopped on his way out and logged out the computer for Grant. Kim also took a particular interest in helping Grant. She spent a good portion of each class period working one-on-one with Grant. When she had been helping someone in class, she would stop by and ask Grant how he was doing on her way back to her computer.

Most of the data I have for Grant is from classroom observations. I do not have a complete survey for Grant; though he did answer a good number of the questions, he missed an entire page and did not type in responses to the open ended items. I did not interview Grant either. He declined when asked if he wanted to be interviewed. And as previously mentioned though, he did finish the project and Ms. Avery graded it, but he did not upload his simulation to the Scalable Game Design arcade.

### ***Pablo***

Pablo's vignette provides an example of a student with high self-efficacy in both mathematics and computers. He preferred to work independently and was a self-starter. He worked quickly and quietly on his project, often anticipating what the class would be asked to do and doing before or while directions were being given. He would enter class, sit in his seat right away, and open the AgentSheets software and the wiki. When he talked with his classmates, the topic was rarely about the project or next steps in programming. When he occasionally worked with a classmate on the project, he was most often in the participant position of learner or student, while the other student was showing him how to do something in the project. Pablo rarely worked collaboratively.

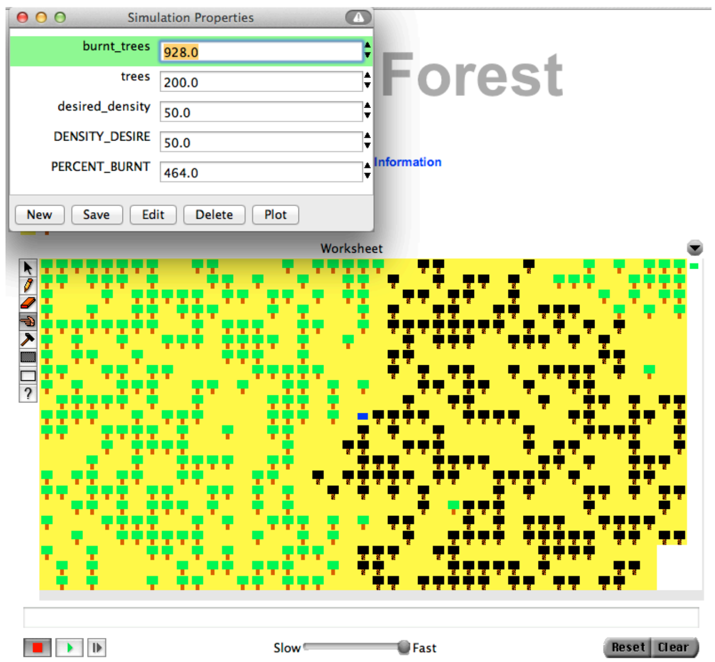
Pablo had taken a 6-week elective class using AgentSheets taught by Mr. Samson and Mr. Connor. He was comfortable maneuvering within AgentSheets and the school servers. Pablo would work quickly and then was in a position of not knowing what to do next. He would raise his hand frequently and would keep it up for a moderate amount of time to try to get help with the next step in the project. The teachers were busy working with students who were behind, and may have given his questions a somewhat lower priority, as he was not in jeopardy of not finishing the project.

Pablo's teacher, Mr. Connor, did not introduce the tutorials on the wiki until well into the unit. Pablo knew how to get into the wiki and would go to the arcade, but he did not know where the forest fire tutorials were initially. Perhaps if he had had this information he could have moved ahead to project completion early and worked on extensions and enhancements.

Pablo was very social and seemed popular with classmates. He was on the school's basketball team and had no shortage of students coming to talk with him. When he was stuck as to where to go next in the project he would carry on side conversations with several other students. These conversations were not related to the project or the use of the AgentSheets software.

Pablo participated in large group discussions during the direct instruction portions of the unit. When Mr. Connor would ask a question to no one in particular, Pablo and one other male student would quickly call out a response. The teacher seemed to take that as evidence of student understanding and move on to the next topic of presentation. For example, Mr. Connor began the second class period of the unit by reminding students where they should resume their work from the previous day. He asked, "What types of trees do we need?" Pablo called out the three types of tree depictions needed for the simulation: living, burning, and burnt. Mr. Connor asked no further questions of any other students in class before moving into the next section of direct instruction.

**Figure 6.6 Pablo's Forest Fire Simulation**




When the teacher was giving general directions while students were on computers, however, Pablo would often work right through these directions, not turning to face the teacher as some other students did. He was able to work through distractions as well, even classmates talking to him while he was working. In one example of this, I noticed that the boy seated across the aisle kept talking to Pablo. This boy was also dressed in a dress-shirt and tie indicating that he was also on the basketball team. Pablo seemed to be friends with this student. This boy was exhibiting off-task behavior, facing away from his computer and not looking at Pablo's computer. The conversation was clearly not about this project. However, Pablo kept his eyes on his screen and continued programming while the boy talked. This lasted for several minutes.

When other student distractions got particularly intrusive, Pablo left his seat to go visit with other students. In one instance, a male student occasionally came over to help Pablo's neighbor with the project. The rows in the lab are tight and when an additional student came to stand by someone's computer it got very crowded. When the help sessions were short Pablo usually persisted in his work. However, while watching an extended help session, I noted,

> Pablo works for a short time but the other student is literally resting his hands on and leaning over his and his neighbor's seats. Pablo gets up and goes to row behind him. The helper sits in Pablo's seat as soon as he leaves. Pablo begins talking with the girls in this row and then walking around the lab. He rubs one students head, fluffs up a girl's hair, and exhibits other off-task behaviors. (Observation Notes, November 2011).

Pablo returned to his seat when this other student left. He began right back in to work, but didn't stay on task very long. He then started to talk with the boy across this aisle, not about the project.

Pablo tended to work intensely on his project while he understood the next steps of what to do. He would continue to work when there were distractions; he even continued to program his simulation while the teacher gave oral directions to the entire class. Often times Pablo was further along in his simulation than the instructions being offered by the teacher. However, when Pablo got off-task, this period lasted longer than for some other students (Lia, for example). Off-task behavior seemed to occur more often after a period of seeking, but not receiving, help and when Pablo was unclear about the next thing to do to complete the project.

He would find someone to talk with rather than sitting idly, and he did not often seek out other students whom he could ask about progressing in the project.

There was one period when I thought that Pablo was working with his neighbor on the project. They were both looking intently at Pablo's computer screen. However, upon closer look, Pablo was showing his Frogger-style game to this student. He had created it in the elective class and had entered the SGD arcade to play the game. Both Pablo and his neighbor took turns playing the game until the teacher asked that they close it until after they had completed the simulation and related activities.

Even with the off-task periods of time, Pablo worked quickly to finish the project. Pablo finished in four days what others in the class took five days to complete. He was absent on the fifth day of the unit and was still able to finish data collection and analysis with the class. At the end of the class periods, Pablo was not one of the first to leave the lab. He wanted to make sure his work was saved correctly in the right spot on the server.

***Damian***

Damian's vignette further illustrates the importance of allowing students to access resources for independent problem solving at all points during the unit. Damian worked steadily when he could use resources to find solutions for his questions, but was derailed when he was required to wait for the teacher or other classmates to catch up in order to proceed to the next portion of the unit.

Damian was a tall Latino student who had many different physical appearances. Even though Damian was tall and popular he was not part of the basketball team as several other students fitting this description were. He had stretched earlobes with large rings forming tunnels in his earlobes; some days he wore larger tubes than others. Some days Damian came to school with 1950's black horn-rim style glasses and no ear jewelry. Other days, he had his thick black hair spiked straight up. He was one of the only students in this conservative community that had a somewhat alternate style of dress. Most of the male students had very short haircuts and wore traditional clothing.

Damian was a very social student, though he tended to work on his project alone. He sat in the far right corner of the lab – the furthest spot away from the teacher and the presentation area and somewhat isolated from other students. When in a whole group setting, like during the direct instruction portions of the unit, he enjoyed being in the spotlight and making classmates laugh. He was particularly popular with the female students in his class.

Damian paid attention to the directions given at the beginning of the class period and got right to work. He finished the pre-survey in about the same amount of time as most other students in class, taking about nine minutes. During the first class period, Ms. Avery walked the students step-by-step through opening and naming the projects and opening the wiki and finding the tutorial for the forest fire simulation. (Ms. Avery may have had students using the tutorial right away because she was not as confident in teaching AgentSheets without the aid of the tutorial, but it seemed to benefit the students and the flow of the class regardless of the initial reason for relying on the tutorial.) When the class was asked to allow for everyone to go through the same steps at the same time and wait until others caught up, Damian got off task talking to students around him. He was already finished with that step, but the students with whom he was talking may or may not have been.

When the teacher gave the students the go-ahead to start their projects, Damian began creating his agents right away. He had drawn three agents already when another student asked how to upload an image from Google to make an agent depiction rather than drawing it by hand. This seemed to jog Damian's memory and he went back and replaced all his depictions with images from Google. Damian then taught his neighbor how to import an image in to AgentSheets. Damian finished his work quickly and searching Google images seemed to help fill some of the down time while Damian waited for the class to catch up.

When the class was asked to gather in the presentation area for the direct instruction portions of the unit, Damian participated in the whole group discussions and often provided silly answers to get a laugh from the class. For example, when asked about who had been up in the mountains lately and what color the trees were now as a result of the beetle kill, Damian said "Purple." The comments were not offensive and did not distract too much from the general flow of the discussion. Damian also provided "real" answers and thoughtful questions in the discussions. When the class was discussing forest fires, he asked, "Has there ever been a case where a tree spontaneously combusted?" He then went on to explain what spontaneous combustion means to another student by saying, "like, it just lights itself on fire." The other student said, "The tree commits suicide?" And Damian replied, "yeah, exactly." The class chuckled at this exchange. Damian was able to bring levity to the group without distracting from the main message and task at hand.

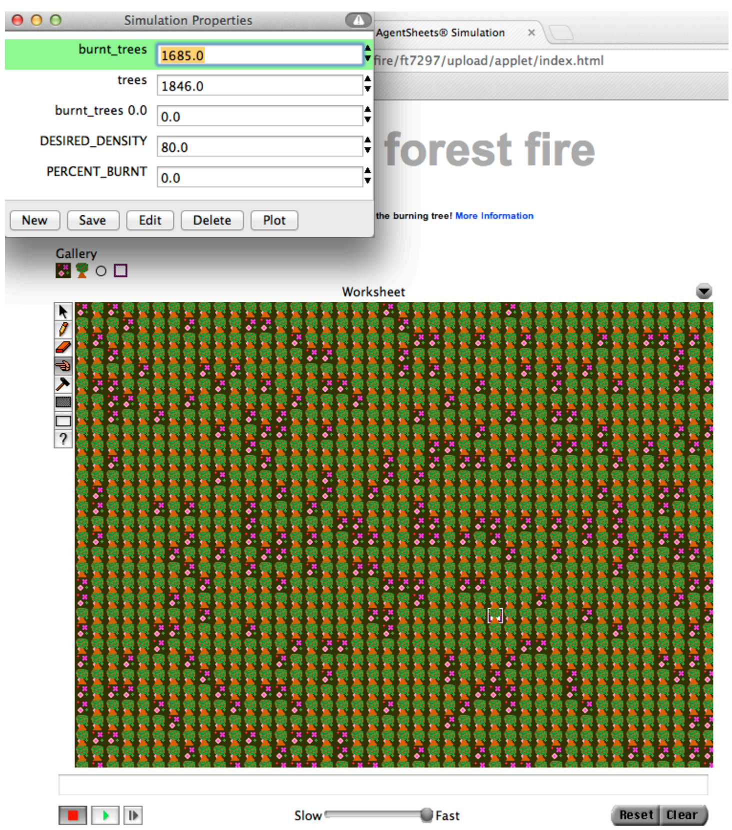
On subsequent days in the lab, Damian opened the tutorial right away (the class was reminded daily to do so by Ms. Avery) and began to follow the tutorial and complete the needed agents and behaviors. Occasionally while working, Damian would make comments aloud to draw attention to himself from classmates. From my observation notes:

> Damian calls out comments occasionally, trying to draw the classes' attention to himself. Not many students respond. This is quite different than when they are in group or teacher lead discussions. Damian usually got several laughs. The

students seem quite involved in their projects, and don't seem to hear his comments or respond to them. Ms. Avery catches him one time as he makes some announcement to the class. She says, "Congratulations, now turn around" directing him back to his computer. No students said anything in response.

Despite his attention seeking and attempts at humor, Damian was able to move quickly through the unit. By the second day of the project, he had programmed his forest fire simulation to the point where fire spread through the trees automatically. The user simply clicked on one tree to set the "fire" and then pushed play and the fire spread from one tree to another. Only about one-third of the students were at this point on the second day.

**Figure 6.7 Damian's Forest Fire Simulation**



Because he moved through the steps quickly in the tutorial, by the middle of Day 2 he began helping other students, mostly the three girls two rows behind him. The conversations were often related to the project and the girls often initiated interaction by calling Damian over for help. Later in the week, Damian and the girls began visiting more frequently and the conversations were more often off-task.

Damian was able to focus on his work despite the distractions in class, though at times he seemed to seek out a diversion from his work. For most of the independent work time, Damian worked by himself on his project. He would ask for help from adults, but not other students. He often figured out what to do from the tutorial without help. I noticed that even when he had his hand was in the air waiting for an adult to help, he was still reading the tutorial. On more than one occasion, I saw him find the answer he was seeking from reading the wiki, put his hand down, and not call over an adult for help even when one was available.

Being able to find his own solutions seemed to work well for Damian. What did not work as well was waiting for the teacher and being asked not to go ahead, or having to wait for group instructions of what to do next. For example, Damian finished his simulation early and was waiting for the teacher to come grade his project before he could use his simulation to collect data for analysis. He ended up waiting most of a class period (over 60 minutes of an 80-minute class) while the teacher graded other students' simulations. Throughout the class, Damian tried to get Ms. Avery's attention to grade his project. Near the end of the period Damian walked over to Ms. Avery and gave it one last attempt; he said, "Miss, I am ready for grading." Damian never did get his project graded that day.

While he was waiting, Damian kept going over to the girls' area. At first he was helping, but over time, the whole group got completely off task. They even moved away from the computers to talk in a corner of the room. Damian was finished, but the girls were not and they ended up wasting most of the class period as well and did not finish their simulations that day.

Damian was absent on the final class period of the unit. During my observations, I noted that Damian wanted to have his simulation graded during the previous class period, but never got it done. Since he was absent on the final day in the lab, he did not have had a chance to upload his simulation. This is too bad because he did all the work to complete it and had plenty of time to upload and collect data in the previous class period. If the class had not come back to the lab the following week, he would have gotten an incomplete for the project when he was already done and waiting to be graded before moving on. Damian and I uploaded his game together during the interview, as it was still missing from the arcade.

Damian was also interviewed in Mr. Samson's class as part of the virus spread simulation during his 7$^{th}$ grade year. In this interview he discussed how he liked using AgentSheets to learn about math. In particular, he talked about how people in his class got different data points when they ran their simulations because each run was unique. By exploring this, he explained, he was able to see how variables were correlated, such as the number of people infected with the virus and the rate of spread. From this interview, I would classify Damian in a triggered interest state. The unit had caught his attention, but he had not moved to a more lasting state of interest. He had a more limited understanding of using AgentSheets to design and program a simulation than he had after his second year of exposure.

During his second year of participation, Damian's initial understanding had been expanded and built upon by repetition of exposure. Damian had transitioned to a maintained interest state. Barron (2010) calls for "expanding the temporal dimension" of learning sciences research studies and ties this to Hidi & Renninger's work showing that "patterns of sustained activity result in more stable interests and areas of expertise" (p. 116). When we have repeated exposure data, as we do with Damian in this study, it becomes clear that a longitudinal approach to future research studies would provide valuable insight into learning and interest development when there are opportunities for sustained or repeated engagement over multiple years.

### *Vignettes Summary*

Each of the focal participants provided a specific example to inform the generalities from the survey and interview sections. Lia's and Grace's experiences highlighted the importance of collaboration for increasing and sustaining engagement, especially for many of the female students. But for some this came at a price. They were not able to complete their tasks as quickly because of the emphasis placed on helping others. Kim was able to better balance the desire to help others with completing her own work on time. She was a higher performing student in class in the past and was able to include the demands of others for help. Considering pairings of students, and teaching ways to efficiently provide assistance to peers, could be incorporated in the unit to help students like Lia and Grace. It is tempting to consider removing opportunities to collaborate if and when a student falls behind, but based on the experiences of Lia, Grace, and Kim this would be a mistake. Grace mentioned that sometimes the motivation to learn the material in the first place was to teach it to her friend. And Kim took some of her analysis work home because she wanted to spend more in class time working with her peers. We would not want to remove these motivations.

Grant's experiences highlighted the accessibility of the unit and the importance of scaffolding over time. He did not upload his simulation, but he was able to complete the project for a grade. By the second week of implementation he was able to complete this task as well; he uploaded his game to the arcade.

Sometimes the experiences of a focal participant even provided a counter example to results from surveys and interviews. From the surveys and interviews we discovered that several students had personally held beliefs that “people like me” don’t do technology. But when observing these same students participating in computer related activities, we see that the student may be actively disrupting his or her beliefs. For example, Pablo thought that only inactive people could be interested and good at computer technology, but he witnessed himself and his peers, who are very active members of sports teams, successfully completing the project tasks and enjoying themselves in the process. This may do more to disrupt these beliefs than a career fair or a lecture about career paths ever could. Though, as we saw in Chapter 5, students also need information about career paths, possible careers, and schooling requirements to enter some of the better-known professions such as becoming a physician or attorney. We must keep in mind that it takes time to change career interests; it is unlikely that we would see much change in a one-month time frame. This emphasizes the need for repeated exposure over time and longitudinal studies to determine “sticking power” of interventions and programs.

Observations of behavior can not only give insight to a student’s in-class learning experiences, but can also provide a lens to what participant positions are available for the students in a given environment, and which of these positions are taken up. Student participation is a function of what students do given what is available for them to do in a particular classroom context (Gresalfi, Martin, Hand, & Greeno, 2009). Participant positions are not necessarily stable; students can flow between different positions, deciding to take up one position in one part of the class and switch to another part way through Other times, the participant position remains fairly constant for a given student throughout the observations. In the following section, we will examine the participant positions taken up by our focal participants.

**Participant Positions**

I began coding behavior with a longer list of participant positions. See codebook in Appendix L. But by putting behaviors on a frequency scale, I was able to combine several codes. For example, I separately coded instances of a student exhibiting behavior that showed he or she was working independently (persistence) and keeping information to him or herself after seeking help from the teacher or the wiki. These were all combined into one entry on a 4-point scale under *Working Independently and Keeping Knowledge to Self*. There are four participant positions on which students are scored: 'Information Seeking from Teacher', 'Information Seeking from Wiki', 'Collaboration and Information Sharing', and 'Working Independently and Keeping Knowledge to Self.' There are two categories for self-efficacy: in mathematics, and with computers, and two other categories related to the research questions and study findings: future pursuits and engagement. The ratings for each of the participant positions, self-efficacy beliefs, future pursuits, and overall engagement are discussed for each of the focal participants in the following text and Table 6.2 provides a summary of these ratings.

**Table 6.2 Participant Position Summary by Focal Participant**

| | | Damian | Grace | Grant | Kim | Lia | Pablo |
|---|---|---|---|---|---|---|---|
| **Self-Efficacy** | Self-Efficacy Mathematics High – Low | Med | Med | Low | High | Low | High |
| | Self-Efficacy Computers High – Low | High | Med | Low | High | Med | High |
| | | | | | | | |
| **Participant Positions** | Info Seeking from Teacher Constantly – Rarely | 2 | 2 | 4 | 3 | 4 | 2 |
| | Info Seeking from Wiki / Tutorial Constantly – Rarely | 4 | 3 | 1 | 4 | 2 | 3 |
| | Collaboration and Info Sharing Constantly – Rarely | 3 | 4 | 2 | 4 | 4 | 2 |
| | Working Independently and Keeping Knowledge to Self Constantly – Rarely | 3 | 2 | 1 | 2 | 2 | 3 |
| | | | | | | | |
| **Other** | Future Pursuits Clear – Undecided | 2 | 4 | * | 4 | 2 | 4 |
| | Engagement High – Low | High | High | Med | High | Med | High |

*Grant was not interviewed; therefore, his future plans were unknown.

**Key:**

Frequency:
- 4 = Constantly
- 3 = Often
- 2 = Occasionally
- 1 = Rarely

Clarity:
- 4 = Clear ideas with concrete plans
- 3 = A few ideas with plans
- 2 = Ideas with no plans
- 1 = Undecided

Because students move between participant positions, I looked at not only which ones were taken up by a given student, but to what extent the student held this position. Therefore, in Table 6.2 the student was rated on a scale from 1-4 on the frequency with which they exhibited behavior aligning with each participant position. On this scale, 1 represents the student rarely taking up this participant position, 2 represents the student occasionally taking up this participant position, 3 represents the student often taking up this participant position, and 4 represents the student constantly taking up this participant position. Also recorded in

Table 6.2 is the clarity of a student's future pursuits as expressed primarily through comments in interviews, but also observed behavior.

The student was given a score on the clarity of their future career interests on a 4-point scale, undecided through clear. The student was also given a score on a self-efficacy scale based on exhibited behavior and comments from interviews, when available. The self-efficacy scale is a three-point scale: high, medium, and low. The student's overall engagement was listed on the same three-point scale: high, medium, and low. This score is based on video taped classroom sessions and point-in-time observations recorded in observation logs.

I will use Lia as an example to describe the coding procedure used to complete Table 6.2. To assign a rating for Lia (and similarly all other focal participants) on the Self-Efficacy, Participant Positions, Future Pursuits and Engagement scales, I totaled all the codes given for week one. I calculated the percent in each coding category by day and then aggregated an overall percent for the week. Table 6.3 shows these percentages for Lia for week 1.

**Table 6.3 Lia's Percentages of Each Code for Week 1**

| Code | Description | % of Codes |
|---|---|---|
| A1.CT | Hi Self-Efficacy Tech | 2% |
| A2.LT | Lo Self-Efficacy Tech | 1% |
| B1.CM | Hi Self-Efficacy Math | 0% |
| B2.LM | Lo Self-Efficacy Math | 2% |
| C1.WI | Seek Info | 16% |
| C2.KI | Keep Info | 0% |
| E1.P | Persistence | 20% |
| E2.C | Collaboration | 27% |
| E3.H | Help from Teacher | 19% |
| E4.Q | Quitting | 1% |
| E5.OT | Off-Task | 13% |
| E6.D | Done | 0% |

Because a large percentage of Lia's coded behavior fell into the collaboration category, showing that Lia took up the *Collaboration and Information Sharing* participant position most often, I assigned a 4 rating for her in this category on Table 6.2. When assigning the number to the category in Table 6.2, I also took into account the magnitude and duration of the coded behavior. For example, though approximately 20% of Lia's coded behavior fell into the *Persistence* category, these instances of independent work without seeking help from the teacher or collaborating with a peer were short in duration. Therefore, I assigned a 2 for Lia in the *Working Independently and Keeping Knowledge to Self* category. In this case, this means that she occasionally took up this participant position, but not for an extended period of time. On the other hand, 16% of Lia's coded behavior fell into the Seeking Information from the Teacher category, but these instances were relatively long in duration. There were times when Lia had her hand in the air seeking help from the teacher for a full five minutes. Therefore, I assigned a 4 to Lia in the Information Seeking from Teacher category on Table 6.2. I followed a similar process for the other categories for Lia, and for other focal participants in all categories. The following, beginning with Lia, describes the focal participants' observed behaviors including assigned frequency ratings.

Lia's expressed thoughts and behavior while completing the pre-survey and during project work led me to code her as having medium self-efficacy and interest in using computers, but low self-efficacy and interest in mathematics. Lia felt comfortable helping others with technology questions to a point, but did not offer to help with mathematics related questions. She was an AgentSheets expert, meaning that she had participated in Simulations in Statistics units using AgentSheets before, but she was absent for the second unit in the previous year so she did not have the same exposure as other students in her class. She was in grade level, not advanced mathematics, in previous years. Lia often collaborated with her peers; the social aspects of learning seemed important to her. She frequently took up the *Collaboration and Information Sharing* participant position (coded as a 4). She also frequently took up *Seeking Information from Teacher* participant position with her many instances of asking for help from the teacher (also coded as a 4). When discussing her future pursuits, she stated in the interview that she had no idea what she would study in college, and said, "I want to be a social worker, but I want to be a doctor, but I want to work in a lot of different stuff." Based on this, Lia was coded a 2 in future pursuits as she had ideas, but no plans for how to reach her careers of interest. Lia was engaged at a medium level overall, with some periods of high engagement and some periods of low engagement.

Grace was coded as having mid-level self-efficacy in mathematics based on comments and observations of her behavior. She had higher self-efficacy in her use of technology, but was still coded as having a medium level of self-efficacy with computers. She had participated in Sim-Stat units the prior year and was in the lower math class based on her previous performance in mathematics. Grace sought knowledge from adults occasionally, coded as 2 on the *Information Seeking from Teacher* participant position. Peer-to-peer interactions were very frequent for Grace. The collaboration she participated in was largely one-sided with Grace providing, but not receiving, help from her friend. Grace shared her knowledge constantly and expressed how she felt responsible for teaching her friend how to complete the project; she rated a 4 on the scale, frequently taking up the *Collaboration and Information Sharing* participant position. She also scored a 4 on the future pursuits scale because Grace had a clear vision of what she would like to pursue as a career and some concrete plans of how to reach this goal. She wanted to own her own bakery after attending the Johnson and Wales Culinary School in Denver. Grace's engagement in the Sim-Stat units was high.

Kim had both high self-efficacy in mathematics and with computers. She defined herself as someone who finished quickly and then helped others. She was in advanced math classes in the past and as a result did not use the AgentSheets software before this unit. Though she was considered an AgentSheets Novice in this study, she quickly grasped the program, completed her project tasks, and provided help to her peers. She even assisted some of those who were considered AgentSheets experts. Kim frequently took up the *Information Seeking from Teacher* participant position, though more often took up the *Information Seeking from Wiki/Tutorial* participant position. She sought help from adults in the computer lab, but also often found the solutions to her questions using the online resources. She shared her knowledge constantly, taking up the *Collaboration and Information Sharing* participant position with a rating of 4 on the 4-point scale. Kim was highly engaged throughout the unit. She was either completing the tasks herself, or helping others to complete their work.

Grant's scores on Table 6.2 are based solely on observations. Grant declined to participate in an interview, so I have no interview responses from him. Grant was rated as having low self-efficacy in mathematics and using computers based on the constant support that he required from the teacher and/or Kim. Grant took up the *Information Seeking from Teacher* participant position nearly constantly throughout the units. Occasionally he asked for help from Kim putting him in the *Collaboration* (but not Information Sharing) participant position. He did not access the wiki or tutorials for support, and did not share knowledge with his peers. Grant was considered an AgentSheets Expert in this study because he was in the lower level mathematics classes that implemented AgentSheets based simulation and game design units. When talking with him in the computer lab, however, he said that he did not remember much about AgentSheets. Though he didn't remember from the previous year, when the class did the second unit less than a month later, he seemed much more confident in his use of the AgentSheets computer program. He was even able to upload his project during the second week of implementation, something that he did not accomplish during the first week. Grant only focused his attention for short periods of time, but he was able to complete the project with help. As a result, I coded his engagement as mid-level.

Pablo frequently took up the *Working Independently and Keeping Knowledge to Self* participant position. Pablo liked to work independently and rarely collaboration with peers, though he occasionally helped a neighbor when asked. When he needed assistance, Pablo first asked the teacher, and then looked for online support if the teacher was not available. He was rated a 2 on the frequency of his taking up the *Seeking Information from Teacher* participant position, and a 3 the frequency of his taking up the *Seeking Information from Wiki / Tutorial* participant position. Pablo had high self-efficacy in mathematics and with computers, and a strong sense of his future pursuits. He stated, "I want to be an NBA player, but everybody's got to have a backup for that. So I want to go to school for law enforcement, I want to be a detective or SWAT. I've wanted to do that for a while now." In his response, we can see that time is an important factor to career decisions. It is not something that tends to change in a short period of time. Though science was Pablo's favorite subject, he had no plans for STEM careers, per se. He did say, however, that law enforcement relied on both mathematics and science, and provided examples to support his premise. Perhaps his experience with the Sim-Stat units did not change his career path, but allowed him to see how math and science are related to his chosen career. If this is the case, this is also a positive result of participation. He did have the occasional off-task period, but Pablo's overall engagement was high throughout the unit.

Damian was a focal participant in the pilot study year of this project as well as the implementation year. He had previously been in lower level mathematics classes and was considered an AgentSheets Expert due to his previous exposure. He had mid-level self-efficacy in mathematics and high self-efficacy in computer use. Damian sought knowledge from adults occasionally, but usually found information on his own using the wiki and tutorials. He was rated a 4 on the frequency of his taking up the *Seeking Information from Wiki / Tutorial* participant position. Even if his hand was in the air seeking help from the teacher, he simultaneously tried to find the solution on his own. When he was not permitted to move ahead until he had his project graded by the teacher, and there was a long wait to get his project reviewed, Damian used this opportunity to help others, to a point. However, when this extended to an entire 90-minute class period, Damian lost interest in helping and began to engage in off-task behavior. Independence and the ability to solve his own questions through online resources were important components to Damian staying on-task. Except for when Damian was required to enter a "holding pattern" while the class caught up, Damian was highly engaged in the unit.

Knowing to what extent participant positions were taken up by each of the focal participants and their self-efficacy beliefs provides a frame for examining their uploaded simulation projects. In the following section, I describe the results of examining and test running each of the focal participants' projects.

**Student Projects**

The majority of the students uploaded their projects to the Scalable Game Design Arcade (http://scalablegamedesign.cs.colorado.edu/sgda/) on Friday of the weeklong project. Others uploaded them the next week when the teachers brought the classes back to the lab for a one-day extension of the project week. Thus, students spent six 90-minute periods, 9 hours of class time total, on the computer lab portion of this unit. Students were given instructions for uploading their simulations, included where to put them in the arcade by school, teacher and project type. Students had individually assigned login numbers that did not identify the student name or id number. Unless students included their names as a part of the simulation or project title, which many did, there was no way to identify an individual student.

Though the projects were uploaded and available for teachers to view, Mr. Connor and Ms. Avery did not chose to use the arcade to grade student work. The teachers expressed that they were unsure how to find all student projects and were worried that there could be lost student work. For this reason, and the fact that their grading rubric (See Appendix E) included a section where the student needed to verbally "summarize the use and importance of a simulation", both teachers graded student simulations in class. This was a rather laborious process in that the teacher had to sit one-on-one with each student as they walked the teacher through all aspects of their simulations. During this time there seemed to be an increase in discipline issues. Perhaps with more familiarity with the arcade and some requested improvements to the functionality of the arcade itself, the teachers would choose to use the Scalable Game Design arcade as a tool to grade students' assignments outside of class time in the future.

In looking at the uploaded simulations, the teachers' concerns did seem to be warranted. Many of the simulations were not in their final form. Students were encouraged to upload their simulations regardless of their stage of completion on Friday of the unit week. We told students that they could, and should, upload newer versions later. However there was not class time specifically designated for re-upload, and it seems that many students did not go back and upload complete versions. To illustrate this point, I will examine the simulations of the focal participants from the video recordings in this chapter: Damian, Grace, Kim, Lia, and Pablo. Grant is not included in this analysis; while he did present his project to his teacher for a grade, he did not upload his simulation to the Scalable Game Design arcade. Screen shots for each of the focal participants are displayed in Figures 6.1, 6.2, 6.4, 6.6, and 6.7 in the Vignette section of this chapter.

Table 6.3 is a graphical display of completed grading rubrics for the Simulation in Statistics projects for each focal participant except Grant. Most of the projects uploaded by the focal participants were complete to a certain point. For nearly all of the projects, the simulation properties were not working correctly. Some of the errors found included simulation properties listing over 100% burnt, reset not working, reset not setting appropriate initial values like 0 trees burned and 0% burnt before a fire is started, simulation properties only displaying or working after user generates a forest or runs the simulation, simulation properties not working correctly for reset screen, simulation property *desired density* is not displayed or there are two fields called variations of desired density which was confusing for the user. Other errors included students placing the *start here* agent in wrong place (illustrating the misunderstanding of the purpose of the *start here* agent to control the initial location of the fire to hold another variable constant) or the fire "jumping" to locations not next to existing flame. This was an error specifically addressed in the tutorial.

**Table 6.3 Focal Students' Simulation Checklist for Completion**

| Simulation Component from Grading Rubric | Damian | Grace | Kim | Lia | Pablo |
|---|---|---|---|---|---|
| Appropriate agents/depictions created | ✔ | ✔ | ✔ | ✔ | ✔ |
| Three depictions for trees | ✔ | ✔ | ✔ | ✔ | ✔ |
| Background agent | ✔ | ✔ | ✔ | ✔ | ✔ |
| Start here agent | ✔ | ✔ | ✔ | ✔ - | ✔ |
| Controller agent | ✔ | ✔ | ✔ | ✔ | ✔ |
| Forest fire worksheet has been created with the appropriate agents | ✔ | ✔ | ✔ | ✔ | ✔ |
| Worksheet displayed when "reset" clicked | ✔ | ✔ | ✔ | ✔ | ✔ |
| Agents communicate with the correct programming language | ✔ | ✔ | ✔ - | ✔ - | ✔ |
| Pointer tool works to start the fire | ✔ | ✔ | ✔ | ✔ | ✔ |
| Fire spreads as real fire would (does not "jump") | ✔ | ✔ | No | No | ✔ |
| Forest regenerates itself at a density specified by the user | ✔ | ✔ | ✔ | ✔ - | ✔ |
| Desired density can be user set | ✔ | ✔ | ✔ | ✔ - | ✔ - |
| Forest created has appropriate number of trees for density selected | ✔ | ✔ | ✔ | ✔ | ✔ |
| Accurate data generated to be used in the summary of the project | ✔ * | ✔ * | ✔ * | No | ✔ * |
| Simulation properties reset to correct values (ex. 0% burnt) | ✔ | No | No | No | No |
| % burnt calculated correctly | ✔ | ✔ ** | ✔ | No | ✔ |
| # of trees burnt counted correctly | ✔ | ✔ | ✔ | No | ✔ |
| # of trees counted correctly | ✔ | ✔ | ✔ | No | ✔ |
| Student can orally summarize the use and importance of a simulation | Unknown | Unknown | Unknown | Unknown | Unknown |
| Overall participation and respect toward guests | Teacher Graded | Teacher Graded | Teacher Graded | Teacher Graded | Teacher Graded |

- Partially completed
* Does not work properly on initial "reset" screen
** Does not reset correctly, but still calculates fine

Students needed to have working simulations, including the simulation properties, to be able to complete the project tasks. Data collection relied on the simulation properties working correctly. Students could not have collected, analyzed, and graphed the average of the points in a meaningful way with percent burned showing above 100% each time, for example. The students had to correct all aspects of their simulations, including the simulation properties, to receive credit from the teacher for the project. If they did not have something working correctly, the teacher would send them back to their computers to work on it and then would grade the project when this error was fixed. We can conclude, therefore, that while students corrected their simulations to get their class grade, they did not upload the most recent version of the simulation to the SGD arcade.

Seeing that many of these uploaded simulations were not complete, and/or not working correctly for data collection, indicates that this is likely the same situation for students who were not focal participants. This supports the teachers' concerns about using the arcade as the sole source for grading projects. Using the arcade for evaluating student projects was also a concern if teachers prefer a standards-based approach to grading, as these teachers did. Ms. Avery and Mr. Connor did not let the grade stand with a single point-in-time measure as the score for the student's project, but rather pointed out the errors and expected students to fix any issues and resubmit the project to the teacher for grading. If the teacher did not have the student on-hand to demonstrate his or her project, and for the teacher to show what still need correcting, there would need to be more time built into the unit for this iterative grading process using the Scalable Game Design Arcade.

Teachers offered some suggested improvements for the Scalable Game Design Arcade to develop it into a Teacher Productivity Tool and repository for to be graded projects. These included:

- Develop an easier way to access class projects.

- Teacher accounts with administrative privileges to see the names (not just assigned student logins) of the students in their classes.
- List all students with upload status including date of last upload and/or upload history.
- One-click capability for students to re-upload new versions of the same project.

The initial purpose of the Scalable Game Design Arcade was to create a place where students could go to see and play others games, though with some enhancements, it could also assist teachers in tracking and grading student work.

One other purpose for examining student's uploaded projects for this study was to see if any patterns existed between engagement rates and project work. Engagement was medium to high for all focal participants, and the projects were mostly complete when uploaded. This makes it difficult to clearly answer the wondering posed at the beginning of this chapter, do engagement rates influence project completion and extension? These are, however, two sets of experiences that shed some light on this question.

Grant was the only focal participant who did not upload his simulation to the arcade at all. He was also the focal participant who exhibited the most off-task behavior. He only engaged for short time periods. Damian's experiences also speak to the engagement-completion question. Damian was on-task when he could work independently, but when forced to wait for the teacher to grade his project, he got off task and did not upload his project during class even though he had finished early. This would have been the perfect opportunity for Damian to be encouraged to complete extension activities and enhancements to his simulation while he waited for grading, but instead he was asked to wait patiently and help others if he could. This did not provide adequate challenge to keep Damian engaged. In both of these cases, it appears that engagement directly influences project completion and extension.

Regardless of focal participants' individual traits and completion of uploaded project files, all focal students were engaged at a medium to high level. Collaboration, independent work, step-by-step instructions from teachers or tutorials on the wiki were all available for students to choose depending on their preferences, needs, and work styles. Students were allowed to fluidly change the amount of support they gave and received throughout the unit. This kept engagement and motivation to complete their work high. In fact, through analysis of the observation logs, we see that engagement was high for most of the students for the majority of both of the units. We examine the results of those logs in the next section.

**Engagement/Participation Logs**

Operationalizing participation as observable behavior can provide insight into student engagement. In this study I operationalized participation in Sim-Stat unit tasks in two main categories: on-task behavior and off-task behavior (Gresalfi, 2009). I further delineated on-task behavior into three sub-categories: independent task persistence, which I coded as *P*, working with a teacher for assistance, coded as *H*, and working collaboratively on the project tasks with one or more other students, coded as *C*. These codes are further defined in the codebook used for this project for all qualitative coding; see Appendix L.

During both weeks of implementation, week one for the Simulation in Statistics unit and week two for the game design unit, I recorded point-in-time observations on diagrammatic participation logs. (See Appendix M). Approximately three times each class period for each class each day, I coded the observable participation behavior for each student in both labs. This resulted in 2,542 point-in-time student observations recorded on observation logs over two weeks. These logs were then aggregated by tallying the number of observations by behavior type for each class each day. The tallies were made for all students and subgroups by gender. These tallies were then entered into Microsoft Excel to calculate the sums of observed behaviors recorded and the percent of total behaviors each represented. The data was separated by implementation week and computer lab to allow for comparisons between weeks and labs. The following trends were observed.

Overall a very high percentage (86%) of observed behaviors were on task. See Table 6.4. On task behaviors included persistence by working independently, collaborating with peers, working with a teacher, or actively seeking help from a teacher. In 63% of the observation points in both labs over two weeks, I observed students persisting on project work. This meant students were working independently toward project completion at their computers. In 7% of the observation points, students were working with a teacher on their project or actively seeking help from a teacher by raising their hands. In an additional 1% of the observation points, students were observed engaged in teacher approved “off-task” behavior such as math skills games. (Ms. Avery gave students permission to play the math skills games when they were done designing and coding their simulations, but before data collection was introduced. She also allowed students to use the math skills games when they were completely done with the project including data analysis and write up.) The percent of behaviors coded as persistence, getting assistance from the teacher and allowed off-task behaviors were approximately equal for both male and female students.

**Table 6.4 Percentages of Point in Time Observations by Behavior Type and Gender**

| **Behavior** | Female | Male | Overall |
|---|---|---|---|
| Persistence (P) | 62% | 63% | 63% |
| Collaboration (C) | 18% | 13% | 15% |
| Help from Teacher (H) | 7% | 7% | 7% |
| On-task | 88% | 84% | 86% |
| Off-task | 12% | 16% | 14% |

In 15% of the observation points, I saw students working collaboratively with each other toward project completion. These behaviors included: students working side by side on two separate projects and helping each other with next steps, one student helping another with a single project, and small groups (3-4 students) gathered around a single computer working together before splitting up to return to work individually. There were differences by gender in collaboration. More female than male students were observed in collaborative behavior, while more male students that female students were observed in off-task behavior. Comparisons by gender will be examined further in a subsequent section of this chapter. (See Table 6.6 and Table 6.7 for a more detailed reporting including analysis by week of implementation and computer lab disaggregated by gender.)

In 14% of the point-in-time observations, I observed students involved in off task behavior. Off task behaviors included being out of one's seat but not collaborating with peers, reading a book or doing other classwork, doing other activities on the computer such as searching images not related to project or playing math skills games without teacher permission.

Additional analysis was conducted comparing participation during the first week of implementation (simulation design) and the second week of implementation (game design). There were interesting differences between the two weeks. There was more on-task behavior in Week 2 in both labs, even though this was the last week before students were dismissed for winter vacation. On-task behavior was about 10% higher for both labs in Week 2 as compared with Week 1. (See Table 6.5). Individually, there was an 8% increase in on-task behaviors for Lab 1 and approximately an 11% increase in on-task behaviors for Lab 2 between Week 1 and Week 2.

**Table 6.5 Percentages of Point in Time Observations by Behavior Type, Week of Implementation, and Computer Lab for all students**

| | Week 1 | | | Week 2 | | | Both Weeks | | |
|---|---|---|---|---|---|---|---|---|---|
| **Behavior** | Lab 1 | Lab 2 | Overall | Lab 1 | Lab 2 | Overall | Lab 1 | Lab 2 | **Mean** |
| Persistence | 61% | 55% | 58% | 71% | 65% | 68% | 66% | 60% | **63%** |
| Collaboration | 17% | 11% | 14% | 18% | 14% | 16% | 17% | 13% | **15%** |
| Help from Teacher | 7% | 9% | 8% | 6% | 7% | 7% | 7% | 8% | **7%** |
| Complete (D) | 2% | 0% | 1% | 0% | 0% | 0% | 1% | 0% | **1%** |
| On-task | 87% | 75% | 81% | 95% | 87% | 91% | 91% | 81% | **86%** |
| Off-task | 13% | 25% | 19% | 5% | 13% | 9% | 9% | 19% | **14%** |

There could be several reasons for the increase in on-task behavior during the second week. Several students were absent during the game design unit, the second week of implementation. Even one or two absent students can change a classroom's dynamic. There is also the possibility that those who had participated in more off-task behavior during the first week of implementation were absent during the second week. Another possibility is that students found the topic of game design more engaging than simulation design. Students also had more experience using the AgentSheets software during the second week. If some of the off-task behavior was a result of frustration surrounding the learning of a new program, this could have been reduced during the second week of implementation. Students could jump right in to their work and continue working because they knew the software better and did not need to wait for instructions of how to complete project tasks.

The higher increase of on-task behavior in Lab 2 over Lab 1 could be for several reasons as well. Since there was large percentage of off-task behavior to begin with in Lab 2, off-task behavior could have experienced regression to the mean, tending to decrease rather than increase overall. More on-task behavior in Lab 2 during the second week could also be a result of Mr. Connor's increased emphasis on students utilizing the wiki and tutorial online resources for this unit. During the second week, Mr. Connor directed students to the available online resources and expected them to use them. Students in Lab 2 had more off-task behavior than students in Lab 1. One possible reason for the different rates of engagement between the labs was the physical arrangement of the computer labs.

Students were in two separate computer labs during independent work time. Students in Ms. Avery's classes were in Lab 1 and students in Mr. Connor's classes were in Lab 2. There were several differences between these two instructional environments. The two major differences were physical space differences between the two labs, and instructional style differences between the two teachers.

Lab 1 was in a much larger room with ample space around the outside of the rows of computers and wider spaces between the rows of the computers. The computers all faced the same direction, so that a teacher could stand at the back of the room and view all computer screens at once. It was easier to address the students while they were at their computers as well by standing at the front or side of the lab. Lab 1 had a presentation set-up for projecting a computer screen on a large screen.

Lab 2 was a smaller room with the same number of computers as Lab 1. The room had been a wood shop previously and computers had been added at a later time. The computers were much closer together and the aisles were very tight. It was a challenge to get to some of the students to assist them. Students were facing in three different directions and it was difficult to see all the screens from any one location in the lab. There was no presentation set up for projecting a computer screen.

Another possible contributing factor to the different rates of engagement between Lab 1 and Lab 2 could be related to the teacher's instructional and classroom management styles. Ms. Avery and Mr. Connor had instructional style differences. From the first day in the lab, Ms. Avery encouraged students to access online resources such as the Scalable Game Design wiki and tutorials to help them with project completion. Mr. Connor did not emphasize the use of online resources. He did mention their existence, but did not spend class time demonstrating how to access the resources, or direct students to open the resources at the beginning of the class period as Ms. Avery did.

Ms. Avery also encouraged students to work together while in the lab. Mr. Connor, on the other hand, asked that students remain in their seats, though they were allowed work with their assigned partner who was sitting next to them. Fewer instances of collaboration were observed in Lab 2. Additional analysis of observation log data was conducted comparing participation based on which computer lab the student was seated. There were interesting differences between the two instructional settings.

The percent of point-in-time observations showing student seeking help from a teacher or working directly with a teacher was approximately the same in both labs (7-8%). See Table 6.5. The discrepancy was between the percent of observed collaborative and independent persistence behaviors, and off task behaviors. In Lab 1, there was a 6% percent higher number of independent persistence observations and a 4% higher number of collaborative observations than in Lab 2. Whereas in Lab 2, overall the number of students involved in off-task behaviors was approximately 10% higher than for students in Lab 1.

A combination of the lab layout, teacher's choices about the degree of emphasis placed on utilizing online materials, and classroom management styles, may have lead to the discrepancies discovered in on-task and collaborative behaviors between the two instructional settings. Differences were also discovered when disaggregating the data by gender. The data were still categorized by week of implementation, and proxy for the instructional setting (Lab 1 versus Lab 2). See Tables 6.6 and 6.7 for comparisons by gender.

**Gender Comparisons**

Persistence behavior was approximately the same for girls and boys; 57% of female students' point-in-time observations in Week 1 were coded persistence, while 59% of male students' point-in-time observations in Week 1 were coded persistence. Persistence behavior increased for both female and male students in week 2, though at a slightly higher percentage for girls than boys. Girls' persistence behavior increased by 11% and boys' persistence increased by 8% in week 2.

Overall, most on-task behavior was higher during Week 2 (game design unit) than Week 1 (simulation design unit) for both boys and girls, though this difference was higher for boys. Boys' on-task behavior increased from 78% to 89% from Week 1 to Week 2 (an 11% increase), whereas girls' on-task behavior was higher than boys' on-task behavior in both weeks, but the increase was not as large from Week 1 to Week 2. Girls' on-task behavior increased from 83% to 92% from Week 1 to Week 2 (an 9% increase).

**Table 6.6 Females' Percentages of Point in Time Observations by Behavior Type, Week of Implementation, and Computer Lab**

| | **Week 1** | | | **Week 2** | | | **Both Weeks** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Behavior** | Lab 1 | Lab 2 | Overall | Lab 1 | Lab 2 | Overall | Lab 1 | Lab 2 | **Mean** |
| Persistence | 62% | 51% | 57% | 71% | 65% | 68% | 67% | 58% | **62%** |
| Collaboration | 20% | 16% | 18% | 20% | 14% | 17% | 20% | 15% | **18%** |
| Teacher Help | 6% | 9% | 8% | 5% | 8% | 6% | 6% | 8% | **7%** |
| Task Complete | 1% | 1% | 1% | 0% | 0% | 0% | 1% | 1% | **1%** |
| On-task | 89% | 77% | 83% | 97% | 88% | 92% | 93% | 83% | **88%** |
| Off-task | 11% | 23% | 17% | 3% | 12% | 8% | 7% | 17% | **12%** |

**Table 6.7 Males' Percentages of Point in Time Observations by Behavior Type, Week of Implementation, and Computer Lab**

| | **Week 1** | | | **Week 2** | | | **Both Weeks** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Behavior** | Lab 1 | Lab 2 | Overall | Lab 1 | Lab 2 | Overall | Lab 1 | Lab 2 | **Mean** |
| Persistence | 61% | 58% | 59% | 69% | 66% | 67% | 65% | 62% | **63%** |
| Collaboration | 14% | 8% | 11% | 15% | 14% | 15% | 15% | 11% | **13%** |
| Teacher Help | 8% | 8% | 8% | 8% | 6% | 7% | 8% | 7% | **7%** |
| Task Complete | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** |
| On-task | 84% | 73% | 78% | 92% | 86% | 89% | 88% | 80% | **84%** |
| Off-task | 16% | 27% | 22% | 8% | 14% | 11% | 12% | 20% | **16%** |

Girls tended to collaborate more than boys, but collaboration was about 5% higher for both boys and girls in Lab 1. And while boys tended to exhibit more off-task behavior than girls, girls were closer to boys in percent of off-task behaviors when collaboration was not encouraged (17% for girls and 20% for boys in Lab 2, as compared with 7% for girls and 12% for boys in Lab 1). There were far more off-task behaviors for both genders in Lab 2. Off-task behavior for all students in Lab 1 was lower (10% lower for girls and 8% lower for boys).

Table 6.8 shows what percentage of the observed behavior for all students can be attributed to female and male students separately.

For example, if 25 point-in-time observations were made of persistence behavior, the table displays what percentage of those were female students and what percentage were male students. This is different than what is displayed in Table 6.6 and Table 6.7 because these tables show in which categories the behaviors observed for just female students or just male students fall. The disaggregation by gender is done before categorization by behavior type in Table 6.6 and Table 6.7, and after categorization by behavior type in Table 6.8.

**Table 6.8 Percentage of Point in Time Observations by Gender**

| | Week 1 | | Week 2 | | Mean of Both Weeks | |
|---|---|---|---|---|---|---|
| Lab 1 | Female | Male | Female | Male | Female | Male |
| Persistence | 52% | 48% | 55% | 45% | 53% | 46% |
| Collaboration | 60% | 40% | 66% | 34% | 63% | 37% |
| Teacher Help | 47% | 53% | 41% | 59% | 44% | 56% |
| Off-Task | 34% | 66% | 27% | 73% | 30% | 70% |
| Lab 2 | | | | | | |
| Persistence | 45% | 54% | 53% | 47% | 49% | 50% |
| Collaboration | 75% | 25% | 55% | 45% | 65% | 35% |
| Teacher Help | 52% | 48% | 57% | 43% | 54% | 46% |
| Off-Task | 44% | 56% | 50% | 50% | 47% | 53% |
| Both Labs | | | | | | |
| Persistence | 49% | 51% | 54% | 46% | 51% | 48% |
| Collaboration | 67% | 33% | 61% | 40% | 64% | 36% |
| Teacher Help | 49% | 51% | 49% | 51% | 49% | 51% |
| Off-Task | 39% | 61% | 38% | 62% | 39% | 61% |

Also visible in this analysis is that in both labs and both weeks, girls tended to collaborate more than boys. On average, of the observed collaborating behavior in Lab 1 (both weeks), 63% were female students and 37% were male students. These numbers were similar to the percentages in Lab 2, 65% of point in time observed behaviors coded collaboration were female students and 35% were male students.

Regardless of the encouragement of collaborative behavior, the ratio of girls to boys who do collaborate remains fairly constant (roughly 2 girls to 1 boy). In other words, for every boy who collaborated, 2 girls choose to work collaboratively. Interestingly, boys tended to collaborate in equal numbers with boys and girls, but girls often worked together first before working with boys, if working with boys at all. Remember that while the percentages of girls and boys collaborating were similar, there were fewer instances of collaboration in Lab 2 than in Lab 1.

When given the opportunity to work collaboratively, off-task behavior was lower, especially for girls. See highlighted cells. On average, of the observed off-task behavior in Lab 1 (both weeks), 30% were female students and 70% were male students. Whereas, observed off-task behavior was much higher for all students in Lab 2, and female students had a larger percentage of the off-task behavior on average as compared with off-task behavior in Lab 1. Of the observed off-task behavior in lab 2 (both weeks), 47% were female students and 53% were male students. In other words, not only were there more instances of off-task behavior in Lab 2, but a larger percentage of this off-task behavior was attributable to female students.

**Participation Log Summary**

Participation operationalized as observable behavior can provide a tangible measure that can give insight into student engagement. In this study I used participation logs for recording on-task and off-task behavior. Analysis of these point-in-time observations led to some interesting findings. The engagement rate was high for all students, with over 86% of the observed behavior being on-task for all students in both labs during both implementation weeks. Engagement was about 10% higher in the second week of implementation, the game design unit, versus the first week of implementation, the simulation design unit. Engagement was also higher for students in an educational setting where collaboration and utilization of online resources was encouraged. Female students engaged in more on-task behavior in general, but especially in these educational settings. Female students also exhibited more collaborative behavior, while male students exhibited more off-task behavior. Both males and females had high rates of persistence behavior.

By observing student behavior, we also gain understanding of the degree of student engagement. Our understanding of student engagement through observation logs and video tape analysis of focal participants, and our knowledge of participant positions taken up by students during these classes can inform several of the research questions for this study. We see that engagement does differ by gender, not in the degree of engagement (it is high for both females and males) but in the nature of the engagement (female students collaborating more than male students). We also see that this data supports portions of Claim 2: Students' social addresses (especially gender) are not good indicators of the level of their engagement and interest in these activities. Female and male students tended to take up different participant positions, however, so contrary to the last part of Claim 2; students' gender did tend to indicate differences in participation.

**Summary**

In this chapter, vignettes of focal students provide in-depth examples of participation in the Simulation in Statistics units. We examined participant positions taken up, the extent to which their projects were complete and working correctly, and the student's engagement over the entire unit. Participation logs provided information about general trends of engagement for the whole group, all eighth grade students at North Middle School.

The Simulations in Statistics and game design units supported a wide range of students' needs and work styles; collaboration, independent work, step-by-step instructions from teachers or tutorials on the wiki were all available for students to choose. The units also had a low threshold for project entry and provided opportunity for success for all. Grant, a special education student with a short attention span, was still successful in project completion when supported by his teacher and classmates.

Students were able to take up a variety of participant positions throughout the units. Some students were more often self-starters like Pablo, some preferred to work independently like Damian, and others preferred collaboration like Lia, Grace, and Kim, and still others benefitted from heavily scaffolding like Grant. Participant positions were not necessarily stable; students could flow between various positions throughout the course of the unit, even within one class period, or choose to stay in one participant position throughout a longer period of time. The fluidity allowed within independent work time kept engagement and motivation high.

Through the combination of data sources in this chapter: vignettes and participation logs, as well as interviews and survey responses, we get a multi-level look at students' experiences during the implementation of these units. The data analysis for this study followed a funnel approach. We started with the entire population to gather more general information, and then chose narrower, and narrower, samples to gather deep information for selected students.

In Chapter 4, the study began with survey data from all students in the eighth grade at North Middle School with parental consent to participate in the research study. All students, approximately 100% of the population, completed the pre and post-surveys. In Chapter 5, the study considered interview data from a representative sample of students in this group. Nineteen students were interviewed, approximately 16% of the population. In Chapter 6, the study examined video tape recordings for in-depth observations of 6 focal students behavior throughout the course of the two weeks of implementation. These 6 students represented about 5% of the population. For both Chapter 5 and 6, a representative sample by gender, race, and previous AgentSheets experience was selected. Then to verify findings within a larger context, participation logs were analyzed for all students in all classes, returning to 100% of the population. Since engagement is a central part of the research questions for this study, we would like evidence of engagement from a larger sample. In this case, we have engagement data from all students in both teacher's classes. This process of gathering general data for all students combined with in-depth data for a sample population provides a robust aggregation for making inferences and suggesting further research.

In Chapter 7, the study will examine the challenges of establishing this longitudinal research study in public K-12 schooling, as well as summarize key findings. It will then interpret findings in context of existing research, and suggest future research in this area.

# Chapter 7. Summary and Interpretation of Findings.

Women and racial minorities are underrepresented in Science, Technology, Engineering and Mathematics (STEM) fields (Hill, et al., 2010), fields that provide many opportunities for lucrative employment. Furthermore, the need for individuals knowledgeable in these areas is ever increasing (Bureau of Labor Statistics, 2011). New STEM teaching approaches and tools are being explored for their potential to disrupt the continuation of the existing inequities by increasing the numbers of underrepresented individuals in the STEM career pipeline. This study explored a program where 8th grade students in a rural middle school used technology as a tool to help solve context-based problems and learn statistics in required mathematics classes. Interest development, participant structures, and engagement of these students during the implementation of technology-enhanced instructional units was documented and analyzed.

This final chapter summarizes the main findings from the data analysis presented in chapters 4, 5 and 6. These findings are related to the research questions posed for this study and current literature. Interpretations and implications of this research are presented, and finally, future research based on this study is suggested. From this chapter, readers are referred to Appendix N, which discusses the complexity and requirements for conducting research in K-12 education, especially during school hours (as opposed to after school settings) and in core content areas such as math and science (as opposed to elective courses).

## Summary of the Study

### Purpose Statement and Research Questions

This study examined the motivational aspects of end-user programming and its applications in content area classes. The data were examined to see if students with repeated participation in the technology-enhanced statistics units had more fully developed interest in mathematics and/or technology that could lead to future study and STEM careers. Data were also analyzed for any differential effect on students' interest in technology and mathematics by gender and race.

The research questions addressed in this study were:

1. What are students' current levels of interest and self-efficacy in technology and mathematics?

    1.1. In what ways does interest development differ for students with repeated experiences using the *AgentSheets* software? (i.e. one, two, or three years of participation).

2. How does the implementation of technology-enhanced mathematics instructional units affect students' engagement?

    2.1. How does engagement differ by gender?

    2.2. What participant positions are available to students throughout the AgentSheets units?

    2.3. How do students take up the available participant positions?

These research questions will work to support or refute my claims:

Claim 1: The Simulations in Statistics units we developed and implemented help transition students' interest levels in technology and mathematics from triggered to maintained situational interest over time.

Claim 2: Students' social addresses are not good indicators of their level of engagement, interest, and participation in these activities. Though the kind of engagement and participation may vary by social address.

## Review of Methodology

### *Participants*

There were approximately 150 middle school students, ages 11-15, recruited for the project. Each of the two $8^{th}$ grade teachers taught 3 sections of mathematics with approximately 25 students in each class (2 x 3 x 25 = 150). Since all students are required to take mathematics, there were approximately 50% female, and 50% male students. North Middle School has a diverse student body. The student population of NMS is approximately: 60% Hispanic, 37% White, and 3% other race including Native American, Asian, and African American. Of its nearly 600 students, approximately 60% qualify for free and reduced lunch and 40% were classified as ESL students.

For the survey analysis there were 117 students with matched pre and post-survey data. For the interviews, a representative sample of 20 students was chosen. Consideration was given to students' gender, race, home language, and previous AgentSheets experience (which also corresponded to previous mathematics performance level). Nineteen of these students agreed to participate in the interviews. Six focal students were chosen based the similar considerations as those for interview participation selection, as well as what participant position(s) the students most frequently took up. These six students consisted of:

- 3 males, 3 females
- 4 Latino/a students, 2 white students
- 3 students from each teacher (Ms. Avery and Mr. Connor)
- 3 students with AgentSheets experience in $7^{th}$ grade
- 1 student received special education support services

***Data Sources***

*Pre and Post-Surveys*

The Student Motivation Survey was developed and validated during the iDREAMS project (Webb & MacGillivary, 2010). A modified version, specific to mathematics classes, was administered online to students prior to the simulation design/statistics units and after they had completed the *Pac-man* style game design unit. There were six constructs in three main categories within the survey: self-efficacy (in math and computers), interest (triggered, maintained due to feeling, and maintained due to value), and future pursuits. See Appendix G, Table G.1, for survey questions by construct. The majority of items measuring interest were developed and validated by Linnenbrink-Garcia et al (2010).

The surveys included Likert-scale items and open-ended response questions regarding student conceptions of mathematics and computer science, experiences with mathematics and computers, and interest in STEM education. Students were asked to describe their interest in continuing to take computer coursework in the near and more distant future (high school and college) and how difficult or easy they felt computers and math were for them.

*Interviews, Student Projects, and Participant Observations*

Nineteen students participated in artifact-based interviews. See Appendix B for interview protocol. For each interview, I downloaded the student's forest fire simulation from the SGD arcade. Students' projects were uploaded to the Scalable Game Design Arcade and were available for teachers and other students to view and play. Using students' simulations to focus the interview allowed students to be comfortable almost immediately as they were talking about something they had just created. This provided a springboard to questions about interests in STEM courses beyond this class and about likely future pursuits. Experiences of individuals from populations historically underrepresented in computer science, such as women and people of color, were of most interest to this project. Therefore, a higher percentage of female and Latina/o students were interviewed.

Participant observations were a main source of data used in this study. Digital video and audio recordings were captured during the two weeks of unit implementation, week one for the Simulations in Statistics unit and week two for the game design unit. This resulted in approximately 100 hours of video recordings and approximately 200 hours of audio-recorded classroom interactions. During both weeks of implementation, I also recorded point-in-time observations of participation behavior on diagrammatic logs (see Appendix M). This resulted in over 2,500 point-in-time student observations recorded on observation logs over two weeks.

*Student Projects*

The majority of the students uploaded their projects to the Scalable Game Design Arcade (http://scalablegamedesign.cs.colorado.edu/sgda/) on Friday of each weeklong project. Students were given instructions for uploading their simulations, included where to put them in the arcade by school, teacher and project type. Students had individually assigned login numbers that did not identify the student name or id number. Unless students included their names as a part of the simulation or project title, which many did, there was no way to identify an individual student.

Students were encouraged to upload their simulations regardless of their stage of completion on Friday of the unit week. We told students that they could, and should, upload newer versions later. However there was not class time specifically designated for re-upload, and it seems that many students did not go back an upload complete versions.

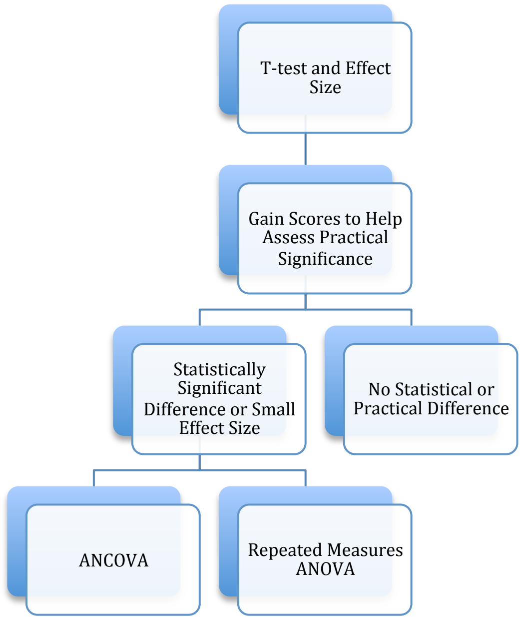
***Data Analyses***

Portions of two previously published surveys were combined to make the survey used in this project. Factors (constructs) had been previously identified through factor actor analysis procedures for these surveys. From the Scalable Game Design Motivation Survey (Webb & MacGillivary, 2010), I used questions from the Self-Confidence, Future Pursuits, and Simulation-Specific factors. From the Situational Interest in Academic Domains Instrument (Linnenbrink-Garcia, et al., 2010), I used questions from the Triggered Interest, Maintained

Interest: Feeling, and Maintained Interest: Value factors. These constructs are theory-based and were shown to hold together in previous factor analysis. Because factor analysis procedures had previously been applied, I ran a Confirmatory Factor Analysis (CFA), followed by an Exploratory Factory Analysis (EFA), and then a second CFA based on the findings from the EFA. Based on the factor analysis results, I retained the 6 original factors identified by the two instruments used in this project for all analyses. Results are reported based on the 6 original constructs: Future Pursuits, Self-Efficacy Math, Self-Efficacy Computers, Triggered Interest, Maintained Interest: Feeling, and Maintained Interest: Value.

Beginning with t-tests and effect sized calculations with the difference of means, and following the flow chart pictured in **Figure 7.1**, two constructs were flagged as possibly having significant pre/post differences for select populations: the Maintained Interest due to Value construct for female students, and the Self-efficacy with Computers construct for white students. Using a paired-samples t test, there was a statistically significant drop in the mean score for female students in the Maintained Interest due to Value construct. There was also a relatively larger effect size indicating an increase between pre and post-survey measures of the Self-efficacy with Computers construct for white students.

**Figure 7.1. Survey Data Statistical Analysis Flow Chart**




Both of these areas were examined more thoroughly using ANCOVA and repeated measures mixed ANOVA statistical procedures. The ANCOVA procedure reduces the within group variance to better isolate any effects of the independent variable. The repeated measures mixed ANOVA takes into account differences in pre-survey scores by including them in the model; making both within subject comparisons (pre and post-survey scores) and between subject comparisons (subgroups by gender and race) in the same calculations.

Upon further examination through ANCOVA and repeated measures ANOVA of these two flagged areas, there were no significant differences found between pre and post-survey in either of these areas. In fact, *there were no statistically significant differences between pre and post-survey results overall or within any constructs or subgroups tested.* In other words, students' scores were stable between pre and post-surveys.

*Qualitative Data Coding*

I coded the fully transcribed interviews by question, combining and summarizing similar responses. These questions were then grouped by larger construct. For example, responses about self-efficacy in mathematics, self-efficacy in computers, and those addressing a student's previous AgentSheets experience level were grouped and analyzed together. Table 3.3, in Chapter 3, shows how interview topics were aggregated into larger constructs for analysis.

After coding the videos for participant positions, I used a narrative description approach to the videotape analysis to create the vignettes in Chapter 6. I then recorded what each focal participant was doing throughout each class period, each day, during the first week in the lab (the duration of the Sim-Stat unit). Finally, based on these notes, I wrote a summary vignette for each focal participant, returning to certain video segments as needed for clarity.

**Major findings**

***Self-Efficacy and Interest: Pre and Post Survey Data***

The first research question of this study was: "What are students' current levels of interest and self-efficacy in technology and mathematics?" Because the survey results were stable, they more likely to be representative of the current levels of interest, self-efficacy, and likely future pursuits in STEM related fields for 8$^{th}$ grade students at North Middle School during the implementation period. Overall, students had high scores on almost all constructs measured. The majority of the selected response questions were Likert-style on a 4-point scale from Strongly Disagree to Strongly Agree. On a four-point scale, the midpoint is 2.5. In this survey, therefore, 2.5 denotes the point between disagree response types and agree response types. The means of the student responses for all students on the post-survey ranged from 2.30 to 3.13, and were above 2.5 for all but one construct[11].

The highest mean was for responses to questions addressing students Maintained Interest due to Value (approximately 3.1). In this case, regardless of the amount of like or dislike the student felt for mathematics, on average students felt the subject was valuable to them. On average, students also felt confident in their use of computers and with mathematics. Students reported high interest (both triggered and maintained) in mathematics and computer use. The lowest mean was for responses to questions addressing Future Pursuits (approximately 2.3). On average, students were not interested in pursuing formal STEM activities beyond middle school such as taking computer classes in high school, or studying computers and/or mathematics in college. Students also indicated that, on average, they did not design computer games at home.

Only the means of responses to questions addressing the Future Pursuits construct were below the midpoint value. The means of responses to all other constructs and the overall mean for the pre and post-survey were greater than 2.5 on average. Though students liked and felt confident in the subjects of mathematics and technology use, and found value in studying them, fewer students planned on pursuing further formal experiences with them in the future.

Using quantitative data analysis results, the answer to one of the research questions posed in this study "Does interest development differ for students with repeated experiences using the AgentSheets software?" is no, not statistically. There were no statistically significant differences between the mean scores for Expert AgentSheets users and Novice AgentSheets users overall or on any of the constructs when comparing means within the pre-survey and

[11] Because the results are similar, I will only report the summary statistics for the post-survey here. For complete results for the pre and post-surveys please see Chapter 4.

within the post-survey (see **Table 4.2**). One possible reason for this is that the AgentSheets software has a low threshold for entry; in other words, students can be successful in initial interactions with the program. Most students who had not been in classes where previous Simulation in Statistics units had been completed were in upper level mathematics classes during the previous school year, and these students, on average, had no statistically lower or higher levels of interest in computers and mathematics.

The largest differences in means between Novice and Expert AgentSheets users were on the pre-survey on the Future Pursuits and Maintained Interest due to Feeling constructs (Δ Mean = 0.17 and 0.16 respectively), though these differences were not statistically significant. Expert AgentSheets users responded more positively to questions about future coursework and experiences with computers and mathematics and liking and being interested in these subjects. These differences closed somewhat in the post-survey, perhaps because all students could be considered "AgentSheets Experts" on the post-survey. This might lend support to the idea that repeated exposure to experiences applying technology and mathematics to solve context-based problems may increase students' liking for the subjects and interest in pursuing future experiences in these areas.

Survey results did support portions of Claim 2: *Students social addresses are not good indicators of their … interest level … in the Simulations in Statistics activities*. On average, the gender or race of the student, or his or her previous level of exposure to Simulations in Statistics units, were not predictors of post-survey scores once pre-survey scores were taken into account. Regardless of the previous level of exposure to the Simulations in Statistics units using AgentSheets, students' race or gender, students had similarly high levels of interest.

As there were no statistically significant differences between pre and post-survey results in the interest constructs, Claim 1: *The Simulations in Statistics units we developed and implemented help transition students' interest levels in technology and mathematics from triggered to maintained situational interest over time* was not supported by quantitative data analysis results. However, interview and open-ended response data provided valuable insight into the triggered and maintained interest constructs and did lend support to this claim. Unlike during the pre and post-survey administration, during the interview process I was able to ask follow-up questions to probe students' experiences and go beyond initial student responses. This provided valuable depth and background information.

***Self-Efficacy and Interest: Interview Data***

Unlike survey data, interview data results support Claim 1. The majority of the students interviewed discussed experiences that provided evidence that their interest states had transitioned from triggered to maintained situational interest states. A few other interviewed students discussed experiences that would suggest that their interest states had moved beyond maintained to emerging individual interest. Interview data also address Research Question 1.1: *In what ways does interest development differ for students with repeated experiences using the AgentSheets software?* Most students who had previous AgentSheets experience spoke of how this helped them during this implementation period. The importance of repeated exposure was often credited for students' increased interest and ability to go further with their projects this year. Some students talked about being able to complete projects for the first time, while others discussed feeling like they could take risks and incorporate more complex features into their simulations and games. The following examples of students' interest transitioning from one state to another were provided in more detail in Chapter 5.

Both Karmen and Pete's shared experiences exemplify a transition from a triggered to maintained interest state during the study implementation year. Karmen participated in the Sim-Stat units during her 7th grade year and said that she had enjoyed them, but during her 8th grade year when she participated again she shared that she was no longer intimidated by her self-perceived lack of knowledge. Upon repeated exposure, she gained confidence to attempt new challenges and her interest had entered a maintained interest state characterized by focused attention over time or in reoccurring episodes. This shift in interest state was not apparent in Karmen's survey results. Karmen started with very high interest on the pre-survey, 3.8 to 4.0 on a 4-point scale. This creates a ceiling effect for Karmen; there is no way to measure an increase of interest if her scores were already at the top.

Pete's experiences also indicated a shift from triggered to maintained interest over time. As with Karmen, Pete's survey results did not show this transition. In fact, Pete's survey results indicated a statistically significant drop in his maintained interest construct. Pete's post-survey scores on both triggered and maintained interest constructs dropped below midpoint, residing in the disagree portion of the scale. This would indicate a lower interest over time, contradictory to what his interview responses indicated. In both Pete's and Karmen's cases, qualitative data, both interviews and observations, showed transitions in interest state. However, evidence of these transitions was not provided by survey data.

Other students discussed experiences that indicated that they had transitioned from a triggered to a maintained interest state during the pilot study year and remained in maintained interest state during the study implementation year. Maintained Situational Interest held from previous school year for Damian, Grace, and Maddie. Still other students transitioned from a triggered to a maintained interest state during the pilot study year, and further transitioned from a maintained interest state to an emerging individual interest state during the study implementation year. Juan was one example of this. Juan was on his way to a well-developed individual interest state, though once again, his survey results did not indicate his transition. Similarly to Karmen, Juan had very high scores on the pre-survey with no way to measure growth in interest. Juan expressed interest in ongoing study of computers, however, without future access to computers (Juan did not have a computer at home), programming software (AgentSheets not available on library computers), and further instruction to support his interests, he may never reach a well-developed individual interest state. As an emerging individual interest still benefits from support from the environment, Juan would benefit from continued computer science coursework at the high school level. Unfortunately these opportunities were quite limited at the high school Juan would likely attend. This leads to the conclusion that *even if interest is developed in STEM fields in the middle grades, without further opportunities this interest may not be sustained to allow students to enter into advanced STEM coursework and ultimately STEM careers*. This has implications for the STEM pipeline.

Additional findings from the interview data were related to the STEM pipeline. Students lacked knowledge about careers in general, and STEM-related careers in particular. It was not just that North Middle School students did not know which career they would pick, but that they lacked information about the range of possibilities, and what picking a particular career meant for future schooling requirements. It was surprising to me how little most students knew about the process of schooling. Considering that these $8^{th}$ grade students would be attending high school in a few months time, it was concerning that many did not know what classes they needed to take in high school, or even what was offered at the high school level.

In future intervention work, we must provide opportunities for engagement and transitioning interest in technology paired with information about how to take this interest further into future schooling and STEM related careers. While approximately 63% of the students interviewed in this study related that participation in the Sim-Stat units had lead them to consider new careers or alternate aspects of careers they were already considering, and approximately 32% of the students interviewed said that they were now considering careers using technology, it would be ideal to interest an even greater number of students in STEM careers. In future research, the inclusion of career education as a part of the unit may be one way to begin to address this goal.

Interview data showed that even when students did not have intentions of going into STEM careers, there was an increase in awareness the supporting role STEM plays in other careers, and an increased interest in technology in general. For example, Pablo shared how law enforcement work used math and science and Gabby discussed how she now had an interest in discovering how technology works at the machine level. She had taken apart her iPod and was interested in knowing how all the components worked together to make her iPod function properly.

Interview data provided a look at students' self-efficacy beliefs as well, addressing the first research question "What are students' current levels of interest and self-efficacy in technology and mathematics?" Because self-efficacy is so context dependent, previous self-efficacy beliefs in mathematics and with technology may or may not be applicable to solving context-dependent mathematics problems using technology as a tool. Even if students had low self-efficacy in traditional mathematics and/or technology, in this new platform there are new ways of thinking and a new context or domain for self-efficacy beliefs. New opportunities were developed for alternate definitions of self-efficacy by expanding the perceived applicability and personal uses of mathematics and technology. In other words, participation in these units gave the opportunity for students to develop new self-efficacy beliefs.

Higher self-efficacy beliefs have been linked to higher achievement in STEM content (Britner & Pajares, 2001) and are key to interest development. If a student does not feel self-efficacious in a particular area, maintained situational or individual interest is not likely to develop; whereas, shifts to higher interest states are more likely to occur for students with high self-efficacy in that area. Students with repeated exposure to the Sim-Stat and game design units had more opportunities to develop high self-efficacy with computers, in particular with design and programming using the AgentSheets software.

Several examples of the importance of collaboration emerged from the interviews. Students said that collaboration was key to their engagement in the project; some discussed that the motivation for learning the material initially was to then be able to support and teach fellow students. More female students than male students engaged in collaborative behavior according to interview responses. This finding was also supported by analysis of the video recording and point-in-time observation data. A few students discussed that the demands from peers became overwhelming at times. In response, we should not eliminate collaboration but instead find ways to support students in peer-to-peer interactions. During the iDREAMS Scalable Game Design summer institute training for teachers, ways to assist students with computer work are discussed. For example, teachers are reminded not to take over by grabbing a student's mouse, but rather guide them to the solution on their own. Teachers are also shown the tutorial and wiki resources and have this information to share with students. To support peer collaboration in future implementations, these techniques should be shared with students as well. This could help to alleviate the burden for those feeling overly depended upon while at the same time encouraging other students to engage in collaboration throughout the units.

The Simulation in Statistics units incorporating the AgentSheets software provided opportunities not usually found in traditional mathematics classes. An affordance of the drag and drop funtionality of the AgentSheets software was that students could avoid the steep learning curve of other computer languages and can focus on the design and creation of their project. The AgentSheets software allowed students to retain agency by being able to make decisions about their mathematical learning. Students have choices about how to accomplish the task and can use multiple strategies within the unit. Resources including teachers, other students, and online wikis and tutorials, were used to assist students in creating a simulation of their own design. Students began with a blank slate, and right from the start were making decisions about graphic design and layout, functionality, and data collection.

Students commented about the ownership they felt by creating their own simulation. Since students utilized the simulation they just created to generate the data needed, students felt ownership not only of the simulation, but also of the data used to learn the related statistics. Statistical and mathematical tools were introduced as a way to make sense of *their* data to answer questions about the context of the simulation. Self-efficacy beliefs and student interest were enhanced by the fact that students were able to use their own data to learn the statistical tools.

Results of the analyses of student interview responses and responses to open-ended survey items addressed Research Question 1 (What are students' current levels of interest and self-efficacy in technology and mathematics?), sub Question 1.1 (In what ways does interest development differ for students with repeated experiences using the AgentSheets software?), Claim 1 (The intervention we developed and implemented helps transition students' interest levels in technology and mathematics from triggered to maintained situational interest over time) and portions of Claim 2 (Students' social addresses are not good indicators of their interest level).

Overall, the interview and open-ended survey response data showed that the majority of students had high levels of interest in both technology and mathematics, though reported interest in mathematics was slightly lower. Students also expressed relatively high levels of confidence and self-efficacy with computers and mathematics. This was true for both male and female students, though Latino/a students expressed lower self-efficacy in both computer use and mathematics than white students. There was a wider gap in self-efficacy beliefs between Latino/a and white students in mathematics than in computer use. This supports Claim 2, that students' social addresses are not good indicators of their interest level, though social addresses do seem to influence self-efficacy beliefs in mathematics and to a lesser extent computer use.

There was also evidence to support Claim 1; several students described experiences that demonstrated interest transitioning from a triggered interest state to a maintained situational interest state. This seemed to correlate with repeated exposure to the Sim-Stats units using AgentSheets to program simulations and games. Students with repeated exposure were more likely to show evidence of transitioning from triggered to maintained interest states.

***Participation and Engagement: Observation and Video-Recorded Data***

Results from the analyses of observation and video-recorded data addressed Research Question 2; "How does the implementation of technology-enhanced mathematics instructional units affect students' engagement?" Overall, engagement was high for all students during both weeks of implementation. Approximately 86% of the over 2,500 observed behaviors recorded in participation logs were of on-task behaviors. For both male and female students observation data highlighted that students were working collaboratively in 15% of the observed point-in-time behaviors. As with the interview data, observation data showed more collaborative behavior for female students than for male students. Lia, Grace, and Kim all collaborated with peers throughout the units, as described in the vignettes presented in Chapter 6. Collaboration was an invaluable and integral part of the Sim-Stat units for these students, if somewhat frustrating at times.

Research Question 2.1 asks, *In what ways does engagement differ by gender?* From analysis of participation logs, we see that the degree of engagement did not differ between males and females, it was high for all, but the nature of engagement did differ between males and females. Female students engaged in more collaborative behavior and male students engaged in more independent work. Male students also engaged in more off-task behaviors by than female students.

Discrepancies in off-task behavior were also discovered between the two different computer labs. There were more off-task behaviors overall in Lab 2, but especially for female students. Of the observed off-task behavior in Lab 1, 30% was by female students. In Lab 2, 47% of the off-task behavior was by female students. Not only were there more instances of off-task behavior in Lab 2, but also a larger percentage of this off-task behavior was attributable to female students. A combination of the lab layout, teacher's choices about the degree of emphasis placed on emphasis placed on utilizing online materials, and classroom management styles, may have lead to the discrepancies discovered in on-task and collaborative behaviors between the two instructional settings. Lab 1 was more spacious and the computers were arranged in a manner more conducive to holding students attention when needed. Lab 1 also had a projection system for showing a computer on a large screen; Lab 2 did not.

The two teachers differed in their instructional and classroom management styles. Ms. Avery encouraged collaboration and utilization of the online resources. From the first day, students were collaborating on their work. Ms. Avery allowed students to be out of their seats and gather at one student's computer. She had a good sense of when this was on-task behavior and asked students to return to their seats if the gathering was not project-related. She also insisted that her students begin each class period by opening the corresponding tutorial on the wiki. On the surface, it appeared that the same structures were in place to encourage collaboration in both labs. However, though Mr. Connor assigned partners to work together and asked that they sit together, he did not allow students to get up out of their seats to assist or get help from others. If students did not work well with their assigned partner, or if their assigned partner could not help them when they needed it, they were left to ask for help from the teacher directly. This created long wait-times for assistance, and a much larger percentage of off-task behaviors. There were some patterns between engagement rates and project work. A lower level of engagement affected project completion and extension. Overall, the learning environment in Lab 1 was much more conducive to on-task behavior and project completion for all students, but especially for female students.

Observation data demonstrated a low threshold for project entry and success for all. Grant, a special education student with a short attention span, was still successful in project completion when supported by his teacher and classmates. In fact, regardless of student needs, the Sim-Stat and game design units supported variety of work styles. Research Question 2.2 asked, *What participant positions are available to students throughout the AgentSheets units?*, while Research Question 2.3 asked, *How do students take up the available participant positions?"* Various participant positions were available and taken up by students. Some students were more often self-starters like Pablo, some preferred to work independently like Damian, and others preferred collaboration like Lia, Grace, and Kim, and still others benefitted from heavily scaffolding like Grant. Participant positions were not necessarily stable; students could flow between various positions throughout the course of the unit, even within one class period, or choose to stay in one participant position throughout a longer period of time. These units allowed fluidity. Collaboration, independent work, step-by-step instructions from teachers or tutorials on the wiki were all available for students to choose depending upon their preferences, needs, and work styles. This kept engagement high and students were motivated to complete their projects.

Research questions for this study were addressed by various data sources: vignettes of focal students provided in-depth examples of participation in the Simulation in Statistics units; video data analysis gave insight into the participant positions taken up; analysis of uploaded simulations explored the extent to which students' projects were complete and working correctly; and participation logs documented students' engagement over the entire unit. The combination of these data sources, as well as interviews and survey responses offered a multi-level look at students' experiences during the implementation of these units.

**Findings Related to the Literature**

This study was conducted at one site from a larger study, the iDREAMS Scalable Game Design project. Previous research in the Scalable Game Design project found that the majority of students, regardless of age, gender, ethnicity, and race, indicated that they were interested in continuing to study technology beyond the initial introduction received as part of project participation (Ioannidou, et al., 2011). Qualitative data results from this study support this finding as well; interest had transitioned from the initial triggered interest state to a maintained interest state for most students.

Approximately one-third of interviewed students indicated an interest in pursuing STEM related careers. This is a relatively high percentage of students given the duration and extent of the intervention. For students who stated that their interest in STEM careers was sparked by this intervention, and not preexisting before the exposure, it would be especially beneficial to conduct follow-up surveys and interviews to see if this interest is maintained. Perhaps ultimate career choices are resistant to change, with transitions requiring a longer period of time and repeated exposure. Longitudinal research is indicated to evaluate impact of these interventions.

In the interviews conducted in the study, white students, regardless of gender, reported higher self-efficacy in both mathematics and computer use than was reported by Latino/a students. This pattern of lower self-efficacy for students of color in mathematics has been explored in the context of stereotype threat research. Because of stereotype threat, students of color and female students may deidentify with these areas and not include them in their self-definition. Then, if this person does not do well in these areas, deidentification protects their self-regard.

The reports of self-efficacy in mathematics for students of color participating in the simulation in statistics units seemed to be in line with research on stereotype threat, with students of color reporting lower self-efficacy than white students. The qualitative analysis results also align with this study’s pre-post-survey analysis results for the self-efficacy constructs discussed in the Subgroup Response Analysis: Race Comparisons section of Chapter

Four. However, when considering students of the same race, there were more students reporting high self-efficacy than low self-efficacy in computer use for both Latino/a and white students. The pattern of stereotype threat for females in both mathematics and technology and students of color with the use of computer technology did not seem to hold in this study.

It is important to understand that any categorization of individuals based on a single self-selected indicator, such as race, will include wide variability within categories. In future analysis of these data, ways to complexify these categories should be considered. Though data on mother's level education attained and immigration status were not collected for this study, students did indicate their primary home language. This information could be incorporated in analyses to begin to address variability within categories.

While many STEM learning environments are not welcoming to girls and people of color (Eisenhart & Edwards, 2004; Margolis, 2008; Misa, 2010), a shift in the educational environment to include all students can support the development of strong self-efficacy beliefs and shifts in interest states for students underrepresented in STEM fields. Changing the learning environment to include more feminist pedagogies can create better learning environment for girls and people of color (Rosser, 2003; Rosser & Kelly, 1994; Rosser & Taylor, 2009).

From the qualitative data gathered in this study we see evidence that there were quite different learning environments in the two computer labs. There were lab set up differences and Ms. Avery and Mr. Connor had instructional style differences. While Ms. Avery encouraged collaboration and use of online resources, Mr. Connor introduced these in ways that reduced their emphasis and potential for student support. On average, there was a higher percentage of on-task behaviors for all students in Ms. Avery's classes, but especially for female students. Ms. Avery had created an environment more conducive to engagement for girls and students of color by incorporating structures to support various work styles and learning preferences. By realizing that “social relations are not external to technology” (Mies, 2008), and encouraging students to work together on their projects, Ms. Avery was able to avoid many of the deterrents to engagement that exist in other learning environments.

Peer-to-peer collaboration is highly engaging for students. Students can self-select into “islands of expertise” (Barron, 2010) and offer guidance to others in class. Other students choose to access this knowledge source for assistance on their projects. This can lead to sustained engagement in the learning activities for both the students offering help and those receiving it. These groups of students work together to create zones of interaction (Shepardson & Britsch, 2006). Shepardson & Britsch (2006) discuss how in a traditional classroom asymmetries in power are linked to asymmetries in access. In this study, student interactions in the computer labs worked to disrupt this asymmetric access and lead to high engagement for a large percentage of students. The fact that the mathematics was situated in a realistic context also helped to maintain high levels of engagement.

The tenets of Realistic Mathematics Education emphasize the importance of situating mathematics in a context that can be used by students to make sense of new learning and link this new learning to previous understandings. Freudenthal (1968, 1991), and others who subscribe to the theories of RME, believe that mathematics education should begin with realistic problem contexts and successive horizontal mathematization to support subsequent vertical mathematization. Modeling of a real world situation creates a context for student learning. Cobb (2002) describes how the intent of the RME approach is to support a “reinvention process” where students mathematize their informal reasoning in problem situations that are real to them (p. 173). Modeling of these situations allows students to pose and solve their own problems and questions. The Sim-Stat units were aligned with the RME approach and demonstrated the power of modeling and simulation design and use.

For this project, data was gathered from the entire population through the pre and post-surveys and participation logs. Data was also gathered from select sample populations through interviews and focal participants of the video recording analysis. The study started with the entire population to gather more general information, and then chose narrower, and narrower samples to gather deep information for a select few students. This process of gathering general data for all students combined with in-depth data for a sample population provides a robust aggregation for making inferences and suggesting further research.

**Implications for Future Research**

Claim 1 (The intervention we developed and implemented helps transition students' interest levels in technology and mathematics from triggered to maintained situational interest over time) was based on over 4 weeks spent in classes with the 8$^{th}$ grade students, and over 13 weeks for 6$^{th}$, 7$^{th}$ and 8$^{th}$ grade students combined in North Middle School over two years. During this time we observed transitioning interest. During the pilot and implementation years, Claim 1 was supported by formal observations and students interview responses. However, survey data did not show transitioning interest over time. The results were stable between pre and post-survey. The discrepancy between the qualitative data results supporting Claim 1 and the survey data results not supporting Claim 1 make it difficult to offer conclusive statements regarding students' transitioning interest states.

The survey instrument, in the way that it was administered in this study, may not be sensitive to changes in states of interest for most students. There are several possible reasons for the discrepancies between the survey responses and the interview responses and observations. Even if students' interests had transitioned from triggered to maintained, the time between the two administrations of the survey may have been too short for the difference to become noticeable on a survey instrument. There were only 6 weeks between the two administrations and one of the weeks was a vacation week. Interest states, self-efficacy and beliefs about possible future career paths can take a considerable amount of time to change. A second possibility is that the survey instrument is not sensitive to small changes in interest. Further item development and testing may be warranted for future research.

A third possibility has to do with the comparisons between AgentSheets Novices and AgentSheets Experts and the particular sample of students in this school. In North Middle School, elective classes using the AgentSheets software were offered to all students. Some students who did not have AgentSheets exposure in their math classes, and would therefore have been considered AgentSheets Novices, took these elective classes. These students then met some of the criteria for AgentSheets Novices and some of the criteria for AgentSheets Experts. This situation created cross contamination between those who had and had not had previous AgentSheets experience and made it difficult to identify a sizeable group of students for whom this was the first exposure to AgentSheets and the Sim-Stats units. This could help to explain the similarities between pre and post-survey scores for students categorized as Novices and those categorized as Experts.

There are implications of these findings and considerations to be made for future research using this survey instrument. The original research studies used to develop the situational interest survey (Linnenbrink-Garcia, et al., 2010), which comprises a portion of the survey questions used in this study, were all single point-in-time measures. Even with a short time period in between survey administrations, two point-in-time measures offer more accurate data for measuring changes in interest states. If the stable results were due to a relatively short time period between pre and post-survey administration, a longer time period between administrations could be considered. However, if there were no additional units in this extended time period, there is little reason to believe that extending the time alone would better reflect interest transitions in survey results.

If the survey results were stable as a result of the survey itself, additional development may be warranted. Factor analysis procedures were applied to this survey. Perhaps applying item response theory could give some insight to item difficulty and differentiation between interest levels for respondents. Enthusiasm and excitement was apparent in middle grades students survey responses; many responded with threes and fours on the pre-survey with little room from growth. If researchers can develop items that are more difficult to agree with for these students, perhaps we could better measure change in interest states.

Other considerations apply to research using survey instruments to support qualitative data collection methods or in lieu of qualitative data collection methods in general. In an era where privilege is given to quantitative research methods, we must wonder when is survey data sufficient and to what extent qualitative data must be used to support quantitative findings for us to be comfortable with the results. In this study, both qualitative and quantitative methods were necessary to answer the research questions. In the nineteen interviews conducted in this study, there were several instances of repeated or similar comments from different students. In ongoing studies, interviewing all students is too time consuming when studies include a large sample of the population, but there may be some proxy for detecting shifts in interest states; perhaps we could flag certain students for follow-up interviews based on survey responses so it would not be necessary to interview a large number of students. With strategic sampling the number of interviews necessary could be reduced.

Another implication for future research and an unanticipated aspect of this study was the challenge of maintaining a research presence in the school district. Ensuring that the research project would be supported and ongoing was something that needed attention from the project team each school year. Appendix N describes the approval process that we followed over the course of the pilot and implementation years. This included formal and informal meetings between the project team and teachers, principals, the entire staff of the school, technology support personnel, and the superintendent of the school district.

## Recommendations for Future Research

Future research suggested by this study is in two main veins: use of existing data and design and implementation of additional research studies.

### *Existing Data*

Additional analysis can be conducted with the data already collected in this project. More detailed analyses of the audio recordings from the lapel microphones could be informative for how the teachers created and maintained the learning environments unique to each computer lab. Hierarchical Linear Modeling (HLM) (Raudenbush & Bryk, 2002; Singer & Willet, 2003) could be applied to the data collected in this project. A 2-Level model, nested by teacher, might provide additional insight into the survey data. After checking that the data meet the assumptions, an unconditional Level 1 repeated measures model could be tested to assess the variability from pre- and post-survey, and Level 2 analysis could assess if there are any teacher level effects. HLM procedures could be applied to either existing data, or incorporated in new studies.

Another suggested analysis with current data is to look for patterns in pre and post-survey means for two groups of students, those with means by construct of 3.5 or greater and those with means by construct of 2.0 or lower. After determining and comparing interest states of those with high means on the pre-survey with those with low means, we could begin to answer the following questions. Are there certain characteristics of those with high early means? How do their open-ended responses compare? Are there patterns between responses to Likert items and open-ended responses and interview responses (when available)? Could this information lead to the creation of a flag based solely on Likert responses for students who may have transitioned interest states?

Other data were collected during this project, but have yet to be analyzed. Analysis of pre and post mathematics content tests and completed student data collection worksheets could be useful for the project team and classroom teachers to inform future unit implementation. This information could be tied to required standards and results from state accountability measures.

***Future studies***

Conducting ongoing research in this area is also suggested by this research. Since the results from the quantitative instruments in this study did not support the findings from the qualitative methods used in this study, the results were inconclusive. Further research is called for to support or dispute any conflicting results. Considerations for these new studies were outlined above in the *Implications for Future Research* section.

Based on the factor analysis results, I retained the 6 original factors identified by the two instruments used in this project for all analyses. Results were reported based on the 6 original constructs: Future Pursuits, Self-Efficacy Math, Self-Efficacy Computers, Triggered

Interest, Maintained Interest: Feeling, and Maintained Interest: Value. However, there was evidence that a 4-factor model was also appropriate for the data. In the 4-factor model, the two self-efficacy constructs were combined and the two maintained interest constructs were combined. The four constructs would then be: Future Pursuits, Self-Efficacy, Triggered Interest, and Maintained Interest. In further research with this instrument, the 4-factor model should be considered as well in analyses.

When considering the design of future research in this area, longitudinal studies would be beneficial to gather data about the same students over time. Following students through high school and beyond could document the existence of repeated opportunities for students to engage in STEM fields and whether or not these opportunities were taken up. Were advanced courses in computer science available for these students? Were there extracurricular opportunities to engage in STEM related activities? Who enrolled in these courses and activities? Follow up surveys or interviews in high school could allow researchers to compare careers of interest for students when they were in middle school as compared with when they were in high school. Developing career interests takes time. Perhaps the early experiences of using technology to solve context-based mathematics problems introduced new possibilities to students or planted career ideas that took time to take hold. Following students over time could provide more information about the impact, if any, of participation in the Simulations in Statistics and other technology-enhanced interventions.

**Concluding Remarks**

Without the support and structure of the parent project, this research would be difficult, if not impossible, to conduct. Because of the iDREAMS project, the original survey development and testing was conducted, the Scalable Game Design Arcade was developed and maintained allowing for students in this research to upload their projects, undergraduate assistants were provided at the schools to aide in project implementation, teacher, and student support, and the iDREAMS summer institutes offered teachers college credit and stipends while receiving training and inspiration for using technology in their classrooms in new and exciting ways.

As a result of this support, this research was able to contribute to the growing body of evidence highlighting the importance of introducing technology early and offering repeated opportunities for students to engage with the content. This research also found that career education is a critical component to STEM education if we want students to understand the career opportunities available and begin to work toward entering those professions. This study highlighted the importance of supporting survey data with qualitative interview and observation data to triangulate findings and expose the practical significance, if not statistical significance, of students' shifting interest states. And finally, this research found that creating a learning environment that allows for many work styles and fluidity of opportunity to shift between participant positions and that is conducive to collaboration and independence through online resources can greatly increase engagement for all, especially for female students.

Providing opportunities for students to engage with STEM material, and to find that they are able to successfully complete the work, allows for strong self-efficacy beliefs to develop. With positive self-efficacy beliefs, students do not hesitate to re-engage with the material in the future, leading to shifting interest states. Students begin with a triggered interest in a subject, but with repeated opportunities for engagement with support, this interest shifts to a maintained situational interest for many students, and for some students interest shifts to emerging and well-developed individual interests. When this happens, these students pursue future opportunities to participate in these activities such as in advanced coursework in high school and college.

The more these opportunities are provided for female students and students of color, the more individuals from these underrepresented groups will enter into the STEM career pipeline. There is an increasing demand for individuals in STEM fields, especially computer science. However, just as this demand is increasing, the percentage of women and people of color entering these professions is at an all-time low. We must find a way to reverse this trend. There is a pool of untapped potential in our girls and students of color. These students could bring fresh perspectives and new ideas to STEM fields while simultaneously providing themselves with lucrative and stable careers.

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# Appendices

## Appendix A. Middle Grades Statistics Instructional Sequence

**Table A.1 Middle Grades Statistics Instructional Sequence (MGSIS) Overview**

| Middle Grades Statistics Strand | 6th Grade | 7th Grade | 8th Grade |
|---|---|---|---|
| **Statistical Concepts** (Tied to CO State Standards) | Univariate Data<br>• Mean<br>• Median<br>• Mode<br>• Range | Univariate Data<br>• Interquartile Range<br>• Distribution<br>• Variance | Bivariate Data<br>• Sampling<br>• Summary Statistics<br>• Interpret Visual Displays<br>o Clustering<br>o Outliers<br>o Linear and Non-linear association |
| **Graphical Representations** (Tied to CO State Standards) *Model-for* | • Line Graphs (case-value) | • Dot Plots w/ Frequency Axis (case-value)<br>• Box Plots (aggregate) | • Scatter Plot (case-value)<br>• Line of Best Fit (aggregate)<br>o Physically Estimate<br>o Determine Equation |
| **Computer Simulation for Data Collection** *Model-of* | Design & Create* *Ecosystem* Simulation<br><br>*or use pre-existing | Design & Create* *Virus Spread* Simulation<br><br>*or use pre-existing | Design & Create* *Forest Fire* Simulation<br><br>*or use Pre-existing |

**Appendix B. Student Interview Protocol.**

*PLEASE NOTE:*
*Interviews are semi-structured to allow for natural conversation and for other related questions to be asked as topics come up. The questions below provide a guideline for areas to be covered. Only students with both signed parent consent and signed student assent forms will be interviewed.*

The purpose of this interview is to document your current experiences with the simulation design unit. This will be used as a reference for future work with this project, other teachers, and middle school students. Your name will not be used in reports. You will only be referred to generally as a participating student. This interview should take approximately 20 minutes.

*a)* So, do you mind if I ask you a few questions about your experiences with the technology-integrated statistics unit?
*b)* Is it okay if this interview is recorded?

Start audio recorder…

Today's date is [**date**]. This is [**interviewer name**] interviewing [**student name**] at [**location**].

As you know, your math class has been doing a technology and statistics unit. You have done lessons both in your classroom and in the computer lab where you designed and programmed a science simulation.

I am interested in finding out from different people how well the simulation/statistics units went this year. I will be talking with students, teachers, and school administrators.

I would like to have you walk me through your simulation: what you designed, how the programming went, how the data collection and analysis using your simulation turned out. I would also like you to share some of your thoughts on the simulation unit as a whole and the AgentSheets software.

Ask student to open his/her simulation and walk you thorough it.

1. Can you describe for the decisions you made as you were designing and creating your simulation?
2. What was interesting about creating the simulation? What was challenging?
3. Did you have Mr. Samson for math last year? If yes, How do you think having previous AgentSheets experience affected what you did this year? Or How did your previous experience change how you approached the simulation this time?
4. What do you think you learned from creating the simulation? What would you do differently if you did it again?
5. What was your experience like using AgentSheets to create your simulation?
6. How did AgentSheets make you think differently about ways to use computers?
7. What do you think you learned about statistics by doing this unit?
8. How did you like the statistics unit that used technology? What do you think about the computer simulation activities?
9. What was your favorite part of the unit? Your least favorite?

10. If you could design a math class that uses computers, what would you like to do?
11. What types of careers are you considering?
12. Are you interested in careers that include science, math, or technology? Why or why not?
13. Did doing this unit change your interest in these types of careers?
14. What classes do you think you will need to take in high school to achieve your career goals? Are you planning to go to college? What will you study?
15. Are there any suggestions or recommendations you would like to pass along about this unit?
16. Anything else?

**Appendix C. Pre and Post Mathematics Content Tests.**

8th Grade Mathematics Content Pre-Test, Page 1

Name: ______________________ Date:______________ Class: __________

1. The following table shows the grams of fat and number of calories for select items at a few fast food restaurants.

| Fast Food Restaurant | Food | Fat | Calories |
|---|---|---|---|
| McDonald's | Grilled Chicken Sandwich | 4 | 252 |
| | English Muffin | 5 | 170 |
| | Chunky Chicken Salad | 4 | 150 |
| Hardee's | Chicken Fillet | 13 | 370 |
| | Grilled Chicken Sandwich | 9 | 310 |
| Arby's | Grilled Chicken Barbeque | 14 | 378 |
| | Light Roast Beef Deluxe | 10 | 296 |
| | Chicken Noodle Soup | 2 | 99 |
| Taco Bell | Bean Burrito | 12 | 380 |
| | Grilled Chicken Burrito | 15 | 410 |
| Domino's Pizza | 2 Slices Ham Pizza | 11 | 417 |
| | 2 Slices Cheese Pizza | 10 | 376 |

***Part A***
On the grid below, create a scatterplot of the data and draw a line of best fit for the data.
Be sure to

- Title the scatterplot
- Label each axis
- Use appropriate scales

***Part B***
Write the equation for your line of best fit:

______________________________

Title: ______________________

***Part C*** Use your line of best fit to answer the following:

a. Taco bell has an item on the menu with 550 calories. How many grams of fat would you predict this item would have?

__________ grams of fat

b. McDonald's also has an item on the menu with 8 grams of fat. How many calories would you predict this item has?

__________ calories

Axis name:______________________

***Part D***
Explain what the slope represents within the context of this problem.

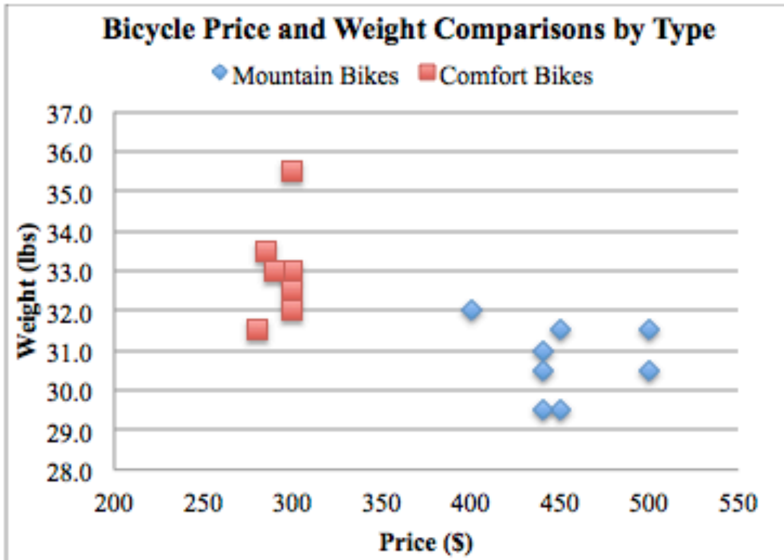
Axis name:______________________

8th Grade Mathematics Content Pre-Test, Page 2

Name: ______________________ Date: ______________ Class: __________

2. Below is a table showing the prices and weights for two different types of bicycles. The data is plotted on the chart next to the table.

| Type | Price ($) | Weight (lbs.) |
|---|---|---|
| Mountain Bikes | 450 | 29.5 |
| | 440 | 29.5 |
| | 440 | 30.5 |
| | 450 | 31.5 |
| | 440 | 31.0 |
| | 500 | 30.5 |
| | 500 | 31.5 |
| | 400 | 32.0 |
| Comfort Bikes | 300 | 33.0 |
| | 300 | 32.5 |
| | 300 | 35.5 |
| | 300 | 32.0 |
| | 280 | 31.5 |
| | 290 | 33.0 |
| | 285 | 33.5 |




***Part A***
Determine and write the equation for your line of best fit for both types of bikes:

______________________________

***Part B*** Use your line of best fit to answer the following:

a. You see an advertisement for a new bike for $200. Based on the above data, what type of bike is this likely to be? ____________
How much would you predict it would weigh? ____________ lbs

b. In the same ad you see another bike for $600. Is this bike more likely to be a mountain bike or a comfort bike? Why do you think so?

How much would you predict this bike would weigh? ____________ lbs

***Part C***
Explain what the slope represents within the context of this problem.

***Part D (BONUS)***
Determine and write the equation for your line of best fit for just the Comfort Bikes

______________________________

Determine and write the equation for your line of best fit for just the Mountain Bikes

______________________________

8th Grade Mathematics Content Post-Test, Page 1

## 8th grade Statistics Unit Post-Test

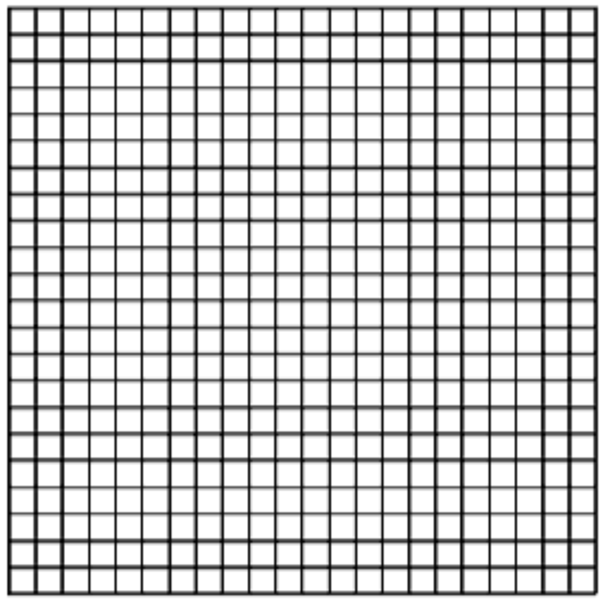
Name: ______________________________ Date: ______________ Class: __________

1. The following table shows the grams of fat and number of calories for chicken sandwiches at various restaurants (data taken from Consumer Reports, September 2004, pp. 30-31)

| Fat (g) | Calories |
|---|---|
| 8 | 370 |
| 4 | 380 |
| 5 | 400 |
| 16 | 400 |
| 24 | 500 |
| 19 | 510 |
| 30 | 540 |
| 23 | 550 |
| 30 | 550 |
| 25 | 570 |
| 19 | 580 |
| 29 | 640 |
| 30 | 720 |
| 40 | 910 |
| 56 | 950 |

Title: ______________________________

Axis name: ______________________________



Axis name: ______________________________

***Part A.*** On the grid provided, create a scatterplot of the data and draw a line of best fit for the data. Be sure to:

- Title the scatterplot
- Label each axis
- Use appropriate scales

***Part B.*** Write the equation for your line of best fit:

______________________________

***Part C.*** Use your line of best fit to answer the following:

a. If Chick-fil-A has a chicken sandwich with 800 calories, how many grams of fat would you predict this item would have?
   __________ grams of fat

b. If McDonald's has a chicken sandwich with 12 grams of fat, how many calories would you predict this item has?
   __________ calories

***Part D.*** Explain what the slope represents within the context of this problem.

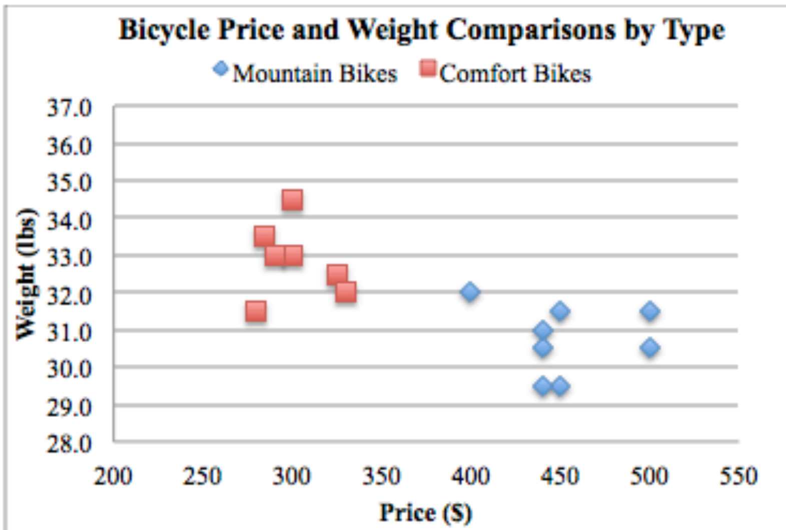
8th Grade Mathematics Content Post-Test, Page 2

## 8th grade Statistics Unit Post-Test

Name: ______________________ Date: ______________ Class: __________

2. Below is a table showing the prices and weights for two different types of bicycles. The data is plotted on the chart next to the table.

| Type | Price ($) | Weight (lbs.) |
|---|---|---|
| Mountain Bikes | 450 | 29.5 |
| | 440 | 29.5 |
| | 440 | 30.5 |
| | 450 | 31.5 |
| | 440 | 31.0 |
| | 500 | 30.5 |
| | 500 | 31.5 |
| | 400 | 32.0 |
| Comfort Bikes | 300 | 33.0 |
| | 325 | 32.5 |
| | 300 | 35.5 |
| | 330 | 32.0 |
| | 280 | 31.5 |
| | 290 | 33.0 |
| | 285 | 33.5 |




***Part A*** Write the equation for your line of best fit for both types of bikes:

______________________________________________

***Part B*** Use your line of best fit to answer the following:

a. You see an advertisement for a new bike for $200. Based on the above data, what type of bike is this likely to be? ____________
How much would you predict it would weigh? ____________ lbs

b. In the same ad you see another bike for $600. Is this bike more likely to be a mountain bike or a comfort bike? Why do you think so?

How much would you predict this bike would weigh? ____________ lbs

***Part C*** Explain what the slope represents within the context of this problem.

***Part D (BONUS)***
Write the equation for your line of best fit for just the Comfort Bikes.
______________________________________

Write the equation for your line of best fit for just the Mountain Bikes.
______________________________________

## Appendix D. Excel Data Collection Worksheet.

| Density | Trial Number | Percent Burnt |
|---|---|---|
| 10 | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | Average: | |

| Density | Trial Number | Percent Burnt |
|---|---|---|
| 20 | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | Average: | |

| Density | Trial Number | Percent Burnt |
|---|---|---|
| 30 | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | Average: | |

| Density | Trial Number | Percent Burnt |
|---|---|---|
| 40 | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | Average: | |

| Density | Trial Number | Percent Burnt |
|---|---|---|
| 50 | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | Average: | |

| Density | Trial Number | Percent Burnt |
|---|---|---|
| 60 | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | Average: | |

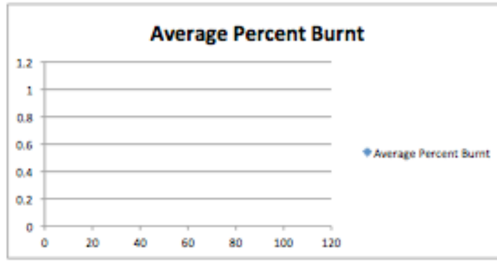
| Density | Trial Number | Percent Burnt |
|---|---|---|
| 70 | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | Average: | |

| Density | Trial Number | Percent Burnt |
|---|---|---|
| 80 | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | Average: | |

| | | |
|---|---|---|
| 90 | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | Average: | |

| Density | Trial Number | Percent Burnt |
|---|---|---|
| 100 | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | Average: | |

| Density | Average Percent Burnt |
|---|---|
| 10 | |
| 20 | |
| 30 | |
| 40 | |
| 50 | |
| 60 | |
| 70 | |
| 80 | |
| 90 | |
| 100 | |




**Reflection:**

**1) Why do you think it is important to run the forest simulation 5 different times at the same density? What does this do for your *sample* of data?**

**2) What is the relationship between how dense a forest is and the percentage of trees that would be burnt during a forest fire?**

**3) Draw in a *line of best fit* for your data.**

**4) Write an equation for your line.**

**5) What does the slope in your equation represent in the context of this problem?**

**Appendix E. Teacher Created Forest Fire Simulation Rubric.**

Forest Fire Simulation Rubric
Name: ________________________________________

1. Appropriate agents/depictions have been created ______/10
2. The forest fire worksheet has been created with the appropriate agents ______/10
3. The agents communicate with the correct programming language ______/30
4. The forest regenerates itself at a density specified by the user ______/20
5. Accurate data generated to be used in the summary of the project ______/10
6. Student can summarize the use and importance of a simulation ______/10
7. Overall participation and respect toward guests ______/10

---------------

Total ______/100

Annotated with "look-fors" from teacher:
Name: ________________________________________

1. Appropriate agents/depictions have been created ______/10
   a. Three depictions for trees
   b. Start here agent
   c. Background agent
   d. Controller agent
2. The forest fire worksheet has been created with the appropriate agents ______/10
   a. Worksheet displayed when reset clicked
3. The agents communicate with the correct programming language ______/30
   a. Pointer tool works to start the fire
   b. Fire spreads as real fire would (does not "jump")
4. The forest regenerates itself at a density specified by the user ______/20
   a. Desired density can be user set
   b. Forest created has appropriate number of trees for density selected
5. Accurate data generated to be used in the summary of the project ______/10
   a. Simulation properties reset to correct values (ex. 0% burnt)
   b. % burnt calculated correctly
   c. # of trees burnt counted correctly
   d. # of trees counted correctly
6. Student can summarize the use and importance of a simulation ______/10
   a. General understanding of simulation use
7. Overall participation and respect toward guests ______/10
   a. Traditional participation grade

---------------

Total ______/100

**Appendix F. Teacher Created Pac-Man Style Game Grading Rubric.**

## Pac-man Grading Rubric

Student Name: ________________________________ Period: ____________

| CATEGORY | 25 | 20 | 15 | 10 |
|---|---|---|---|---|
| Artwork | Artwork shows effort and is 3D and/or creative (not the standard Pac-man, Ghosts, etc.) | Artwork shows effort, but is not 3D or especially creative. | Some effort is evident in artwork, though some agents may be overly simple. | Little effort in artwork. |
| Programming-Movement | Pac-man has user-controlled movement, depiction changes with movement, and ghosts chase Pac-man (Diffusion). | Pac-man has user-controlled movement, depiction changes with movement, Ghosts move randomly. | Pac-man has user-controlled movement, but depiction may not change or ghost movement has problems. OR Pac-man can move through walls. | 2 or more issues with movement. |
| Programming-Pellets | Pac-man "eats" the pellets and superpellets that change ghosts somehow. | Pac-man "eats" pellets, no superpellets. | Pac-man does not "eat" pellets, but can move over them. | There are no pellets or Pac-man can't move over them. |
| Programming-End of Game | Game ends when Ghost deflates Pac-man or all pellets are "eaten." User is taken to next level (Game ends after next level). | Game ends when Ghost deflates Pac-man or all pellets are "eaten." User sees Game Over message and worksheet resets. | Game ends in only one situation or user is not notified/ game is not reset. | Game does not end. |

**Extra Credit:**

- Pac-man has multiple lives _________/10
- There is a game counter that keeps track of pellets eaten _________/10
- There is more than one level _________/10
- Pac-man can disappear through tunnels and reappear on the other side of the screen _________/5
- Pac-man is able to shoot at ghosts _________/10
- Multiple Pac-men _________/5

**Appendix G. Student Surveys.**

**Table G.1 Survey Questions by Construct**

| **Interest** | |
|---|---|
| *Triggered* | My math teacher is exciting. |
| | When we do math, my teacher does things that grab my attention |
| | This year, my math class is often entertaining. |
| | My math class is so exciting it's easy to pay attention. |
| | I usually understand what is talked about in class.* |
| | Time goes fast when I am solving math problems.* |
| *Maintained Feeling* | What we are learning in math class this year is fascinating to me. |
| | I am excited about what we are learning in math class this year. |
| | I like what we are learning in math class this year. |
| | I find the math we do in class this year interesting. |
| | I enjoy the work I do in this class.* |
| | I enjoyed using the simulation on the computer.* (post only) |
| *Maintained Value* | What we are studying in math class is useful for me to know. |
| | The things we are studying in math this year are important to me. |
| | What we are learning in math this year can be applied to real life. |
| | We are learning valuable things in math class this year. |
| | This activity helped me understand the connection between computer simulations and math.* (post only) |

| **Self-efficacy** | |
|---|---|
| *Computers* | Using computers is easy for me.* |
| | I am confident in my ability to use computers.* |
| | I am good at solving computer problems.* |
| | I enjoy taking to other people about technology.* |
| *Math* | Doing math is easy for me.* |
| | I am confident in my ability to do math.* |
| | I am good at solving math problems.* |
| | I enjoy talking to other people about math.* |

| **Future Pursuits** | |
|---|---|
| *STEM Related Future Pursuits* | I design games at home on a computer.* |
| | When I get to high school, I want to take computer classes.* |
| | I would like to study math in college.* |
| | I would like to study computers in college.* |
| | I would like to use computer simulations in math class again.* (post only) |

* *Items also on iDREAMS Motivation Survey*

*PLEASE NOTE:*
*These questions were administered via the online survey instrument service Survey Monkey. The first question was the student assent form, which needed to be agreed to before students were allowed to take any further questions in the survey. The survey was a modified version of the Motivational Survey developed and validated during the iDREAMS project (Webb & MacGillivary, 2010). Additional questions based on Linnenbrink-Garcia, et al (2010).*

## Survey Questions as They Appear in Online Administration

We would like to find out a little more about you and how you feel about math and computers. Your answers to the following questions will help us do this. It will take you about 15 minutes to complete this survey. If you are unsure of how to answer a question, please answer it as best you can. All the information provided is confidential. It will be used to help us learn about how to keep students interested in computer and math education.

1. Who is your teacher?
2. Do you do any of the following activities on the computer? Check as many or as few as needed.
   a. Use website
   b. Create web sites
   c. Play games
   d. Create games
   e. Read wikis
   f. Add content to wikis
   g. Create wikis
   h. View videos on youtube.com
   i. Upload videos
   j. Create video
   k. Maintain a social networking page such as myspace or facebook
   l. Create music (such as garageband)
   m. Computer programming
   n. Other, please describe: ______________
3. Do you have a working computer at home that you use?
   a. (Skip logic if yes) Do you have an Internet connection on your home computer?
4. Please check all the computer classes you have taken:
   a. Keyboarding
   b. Applied Technology
   c. PowerPoint
   d. Microsoft Applications
   e. Internet Safety
   f. Game Design
   g. None
   h. Other (please specify): _____________
5. Which school years did you use the AgentSheets software?
   a. This is the first time I have used AgentSheets
   b. This year and last year (I used AgentSheets last year in math class).
   c. For 3 years (I used Agent Sheets this year and for the last two years in math or Spanish classes)
6. How much to you agree or disagree with each of the following statements? (Likert style question with four categories: Strongly Disagree, Disagree, Agree, Strongly Agree)
   *Computer Interest Questions*
   a. Using computers is easy for me.
   b. I am confident in my ability to use computers.
   c. I am good at solving computer problems.

   d. I usually understand what is talked about in class.
   e. I enjoy the work I do in this class.
   f. I design games at home on a computer.
   g. When I get to high school, I want to take computer classes.
   h. I would like to study computers in college.
   i. I enjoy taking to other people about technology.

7. How much to you agree or disagree with each of the following statements? (Likert style question with four categories: Strongly Disagree, Disagree, Agree, Strongly Agree)
   *Mathematics Interest Questions* (Part 1)
   a. This year, my math class is often entertaining.
   b. Doing math is easy for me.
   c. My math teacher is exciting.
   d. We are learning valuable things in math class this year.
   e. I like what we are learning in math class this year.
   f. I am confident in my ability to do math.
   g. What we are learning in math class this year is fascinating to me.
   h. I am good at solving math problems.
   i. My math class is so exciting it's easy to pay attention.

   *Mathematics Interest Questions* (Part 2)
   a. What we are studying in math class is useful for me to know.
   b. Time goes fast when I am solving math problems.
   c. The things we are studying in math this year are important to me.
   d. When we do math, my teacher does things that grab my attention.
   e. I would like to study math in college.
   f. I am excited about what we are learning in math class this year.
   g. I find the math we do in class this year interesting.
   h. I enjoy taking to other people about math.
   i. What we are learning in math this year can be applied to real life.
8. *Post STEM Simulation/ Statistics Activity Specific Questions*
   - I enjoyed using the simulation on the computer.
   - This activity helped me understand the connection between computer simulations and math.
   - I would like to use computer simulations in math class again.

   Open ended questions:
   - What do you think about the computer simulation activities?
   - How did AgentSheets make you think differently about ways to use computers?
   - If you could design a math class that uses computers, what would you like to do?

The next questions tell us a little bit about you.

1. Are you a girl or a boy?
2. What is the primary language you speak at home?
3. What is your ethnicity?
4. What grade are you in?
5. How old are you?
6. What is your birthday?

Thank you for taking the time to complete this survey.

## Survey Question Numbers by Construct with Open-Ended Questions

| Question Number | Construct Code | Construct Number | Question Stem |
|---|---|---|---|
| 6 | FP | 1 | I design games at home on a computer. |
| 7 | FP | 1 | When I get to high school, I want to take computer classes. |
| 8 | FP | 1 | I would like to study computers in college. |
| 23 | FP | 1 | I would like to study math in college. |
| 1 | SC | 2 | Using computers is easy for me. |
| 2 | SC | 2 | I am confident in my ability to use computers. |
| 3 | SC | 2 | I am good at solving computer problems. |
| 9 | SC | 2 | I enjoy talking to other people about technology. |
| 11 | SM | 3 | Doing math is easy for me. |
| 15 | SM | 3 | I am confident in my ability to do math. |
| 17 | SM | 3 | I am good at solving math problems. |
| 26 | SM | 3 | I enjoy talking to other people about math. |
| 20 | SM* | 3 | Time goes fast when I am solving math problems. |
| 4 | TI* | 4 | I usually understand what is talked about in class. |
| 10 | TI | 4 | This year, my math class is often entertaining. |
| 12 | TI | 4 | My math teacher is exciting. |
| 18 | TI | 4 | My math class is so exciting it's easy to pay attention. |
| 22 | TI | 4 | When we do math, my teacher does things that grab my attention. |
| 14 | MF | 5 | I like what we are learning in math class this year. |
| 16 | MF | 5 | What we are learning in math class this year is fascinating to me. |
| 24 | MF | 5 | I am excited about what we are learning in math class this year. |
| 25 | MF | 5 | I find the math we do in class this year interesting. |
| 5 | MF* | 5 | I enjoy the work I do in this class. |
| 13 | MV | 6 | We are learning valuable things in math class this year. |
| 19 | MV | 6 | What we are studying in math class is useful for me to know. |
| 21 | MV | 6 | The things we are studying in math this year are important to me. |
| 27 | MV | 6 | What we are learning in math this year can be applied to real life. |
| 28 | SS | 7 | I enjoyed creating the forest fire simulation on the computer. |
| 29 | SS | 7 | The forest fire activity helped me understand the connection between computer simulations and math. |
| 30 | SS | 7 | I would like to use computer simulations in math class again. |

Open-Ended Questions:

What do you think about the computer simulation activities?

How did AgentSheets make you think differently about ways to use computers?

If you could design a math class that uses computers, what would you like to do?

KEY:

FP – Future Pursuits
SC – Self-efficacy Computers
SM – Self-efficacy Mathematics
* Dispositions toward Class

TI – Triggered Interest
MF – Maintained Interest: Feeling
MV – Maintained Interest: Value
SS – Sim-Stat Specific questions

**Appendix H. Confirmatory Factor Analysis Diagrams and Fit Indicies.**

**Figure H.1 Theory-Based Confirmatory Factor Analysis Diagram**

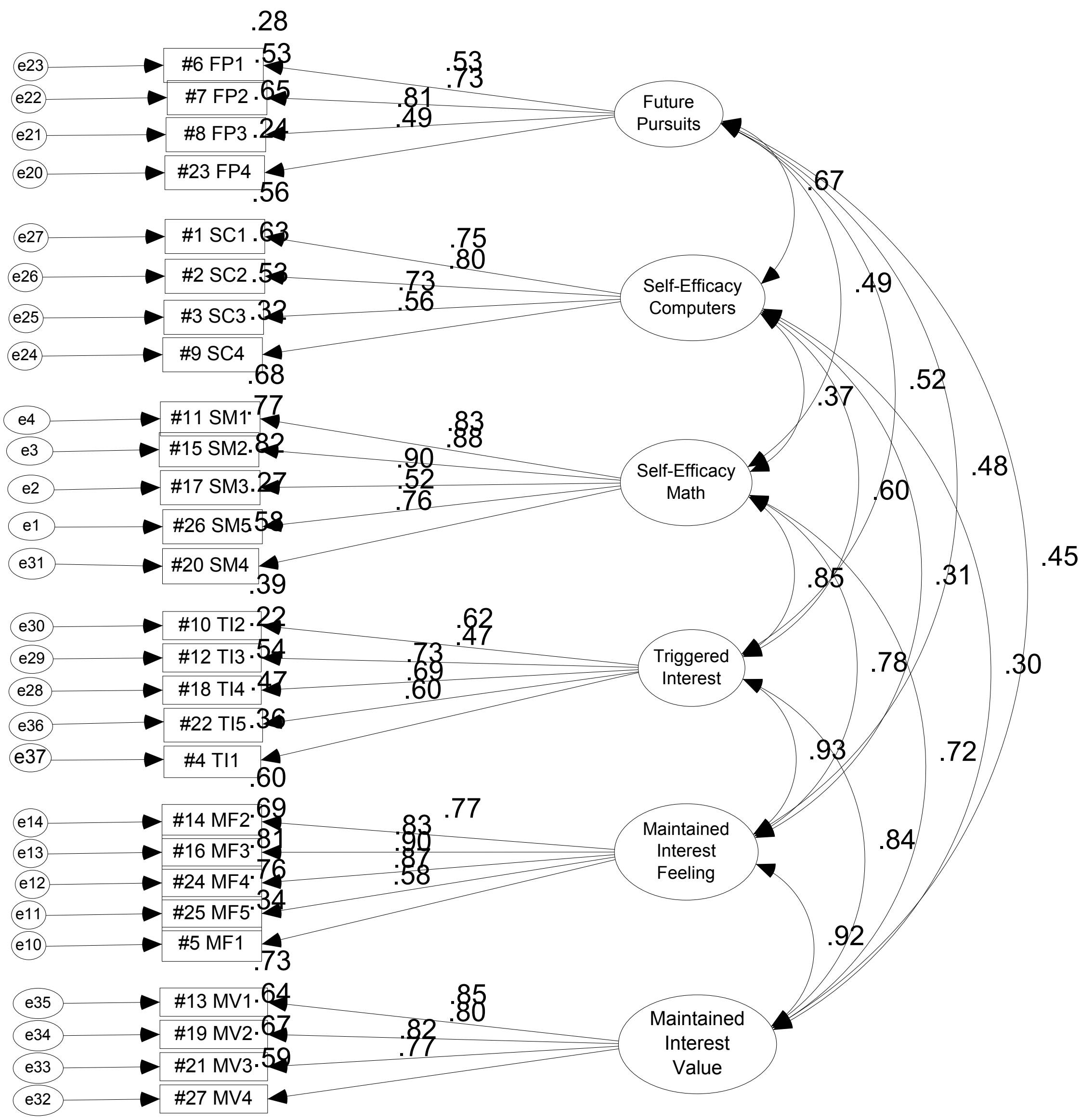
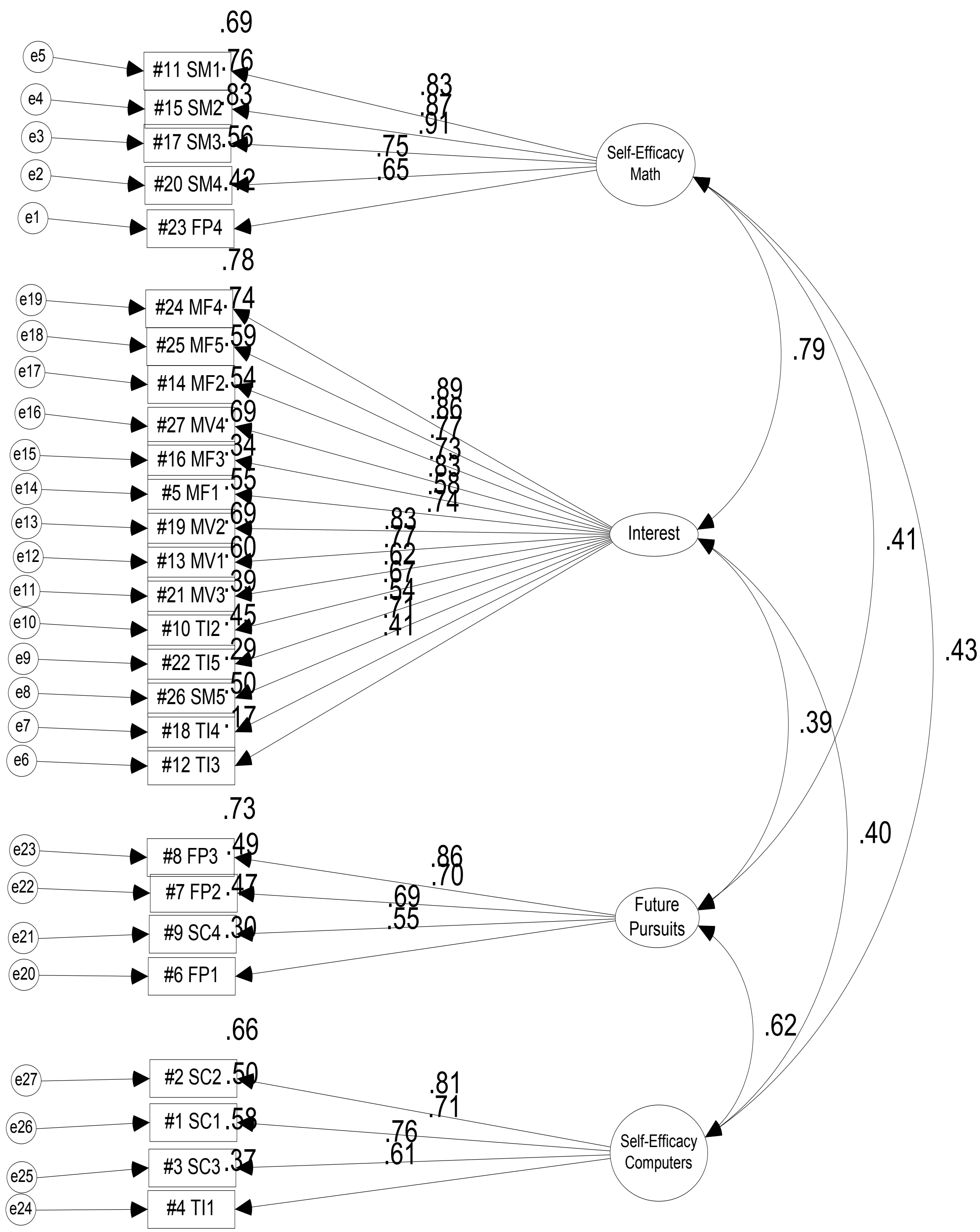


**Table H.1 Fit Indices for Theory-Based CFA and CFA Post Exploratory Factor Analysis**

| | 6-factor Theory-Based Model | 4-factor Model (after EFA) | Acceptable Range |
|---|---|---|---|
| Iterations | 14 | 14 | |
| Chi-Squared | 607.4 | 587.5 | |
| df | 309 | 318 | |
| CMIN/DF | 1.966 | 1.847 | < 2.0 |
| p | .000 | .000 | > .05 |
| | | | |
| GFI | .743 | .745 | > .9 |
| CFI | .857 | .871 | > .95 |
| RMSEA | 0.089 | 0.084 | < .06 |

**Figure H.2 Confirmatory Factor Analysis Post Exploratory Factor Analysis Diagram**



**Appendix I. Pattern Matrices for Exploratory Factor Analysis.**

**Table I.1 Pattern Matrix for Four-Factor EFA**

**Pattern Matrix[a]**

| | Factor | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| #17 SM3 | 1.009 | .066 | -.059 | .009 |
| #15 SM2 | .646 | .119 | .219 | -.046 |
| #11 SM1 | .627 | .023 | .204 | .127 |
| #20 SM4 | .475 | -.048 | .361 | .039 |
| #23 FP4 | .350 | .226 | .322 | -.118 |
| #8 FP3 | -.093 | 1.068 | -.002 | -.154 |
| #7 FP2 | .007 | .618 | .078 | .039 |
| #9 SC4 | .050 | .572 | -.048 | .144 |
| #6 FP1 | .078 | .428 | -.007 | .099 |
| #25 MF5 | .061 | -.081 | .869 | -.030 |
| #24 MF4 | .084 | -.037 | .852 | -.003 |
| #19 MV2 | -.023 | .078 | .776 | -.161 |
| #27 MV4 | .013 | -.095 | .770 | .003 |
| #14 MF2 | -.011 | .111 | .769 | -.122 |
| #21 MV3 | .040 | .051 | .743 | -.054 |
| #13 MV1 | .128 | .039 | .734 | -.034 |
| #16 MF3 | .233 | .016 | .666 | -.031 |
| #5 MF1 | -.173 | .090 | .624 | .209 |
| #22 TI5 | .104 | -.041 | .570 | .175 |
| #10 TI2 | .016 | .028 | .568 | .120 |
| #18 TI4 | .324 | .010 | .444 | .106 |
| #26 SM5 | .203 | .044 | .388 | -.036 |
| #12 TI3 | -.058 | .072 | .355 | .257 |
| #2 SC2 | .004 | .088 | .004 | .800 |
| #1 SC1 | -.049 | .071 | -.038 | .785 |
| #3 SC3 | .262 | .312 | -.029 | .459 |
| #4 TI1 | .290 | .033 | .160 | .426 |

Extraction Method: Maximum Likelihood.

Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 7 iterations.

**Table I.2 Pattern Matrix for Five-Factor EFA**

**Pattern Matrix[a]**

| | Factor | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| #17 SM3 | 1.036 | .037 | -.067 | .014 | -.053 |
| #15 SM2 | .694 | .105 | .102 | -.056 | .165 |
| #11 SM1 | .637 | .002 | .206 | .153 | -.057 |
| #20 SM4 | .518 | -.050 | .224 | .026 | .201 |
| #23 FP4 | .362 | .224 | .347 | -.086 | -.074 |
| #26 SM5 | .246 | .057 | .243 | -.052 | .228 |
| #8 FP3 | -.076 | 1.033 | -.002 | -.118 | .037 |
| #7 FP2 | -.016 | .613 | .191 | .092 | -.201 |
| #9 SC4 | .051 | .564 | -.058 | .157 | .014 |
| #6 FP1 | .095 | .429 | -.080 | .089 | .119 |
| #27 MV4 | -.012 | -.086 | .900 | .083 | -.242 |
| #25 MF5 | .086 | -.063 | .815 | .010 | .051 |
| #24 MF4 | .112 | -.021 | .787 | .035 | .070 |
| #19 MV2 | -.002 | .098 | .758 | -.119 | .007 |
| #14 MF2 | .024 | .132 | .690 | -.093 | .104 |
| #21 MV3 | .067 | .068 | .673 | -.026 | .100 |
| #13 MV1 | .163 | .052 | .641 | -.010 | .132 |
| #16 MF3 | .260 | .028 | .606 | -.003 | .069 |
| #22 TI5 | .129 | -.032 | .479 | .190 | .111 |
| #5 MF1 | -.143 | .109 | .467 | .214 | .258 |
| #10 TI2 | .066 | .034 | .359 | .109 | .351 |
| #2 SC2 | -.025 | .063 | .001 | .834 | -.042 |
| #1 SC1 | -.067 | .047 | -.101 | .792 | .084 |
| #3 SC3 | .243 | .290 | .014 | .499 | -.123 |
| #4 TI1 | .285 | .014 | .141 | .452 | -.009 |
| #18 TI4 | .397 | .003 | .139 | .064 | .538 |
| #12 TI3 | -.027 | .069 | .188 | .248 | .284 |

**Appendix J: Computer Lab Diagrams.**

**Figure J.1 Lab 1 Diagram**

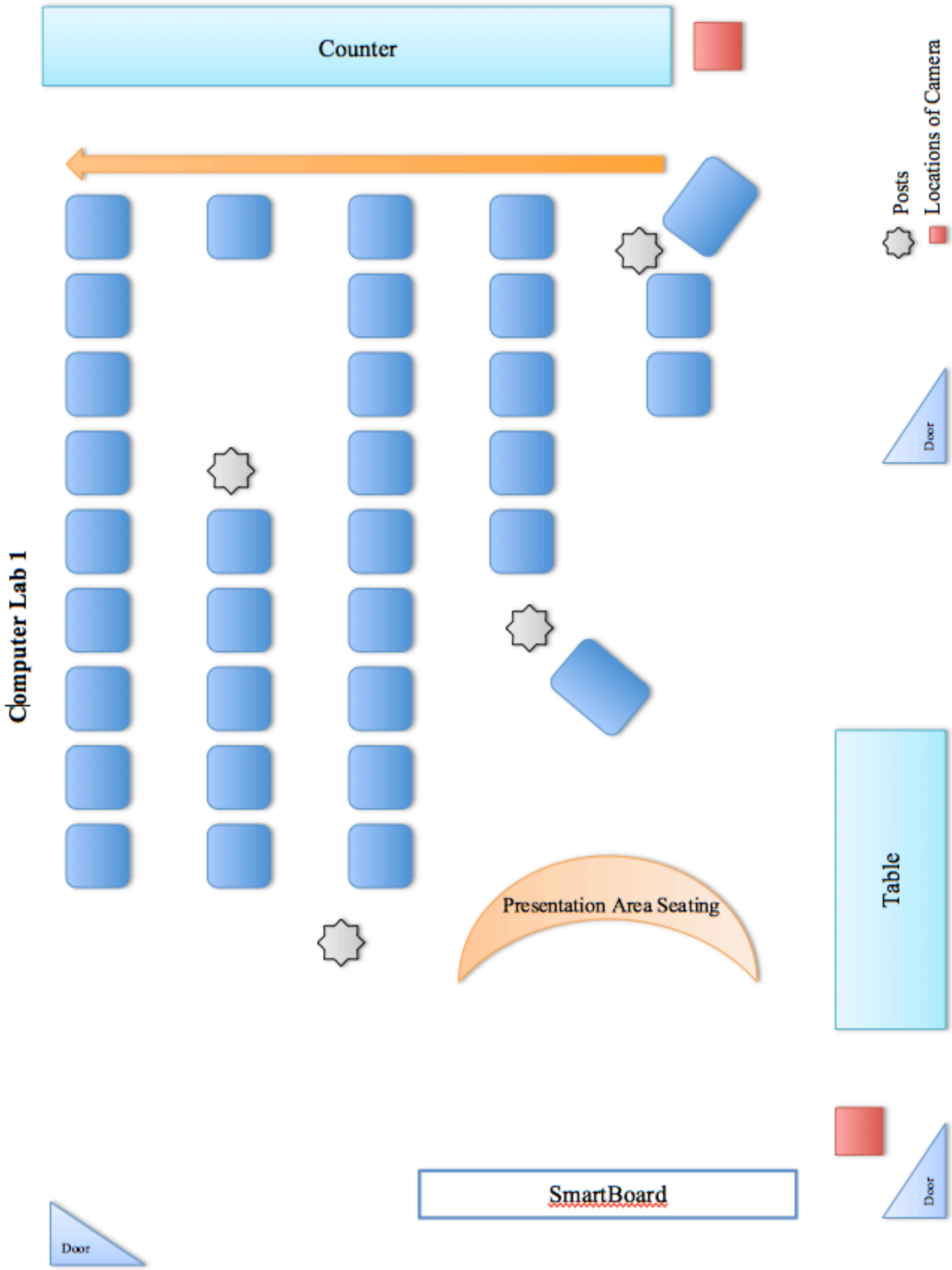
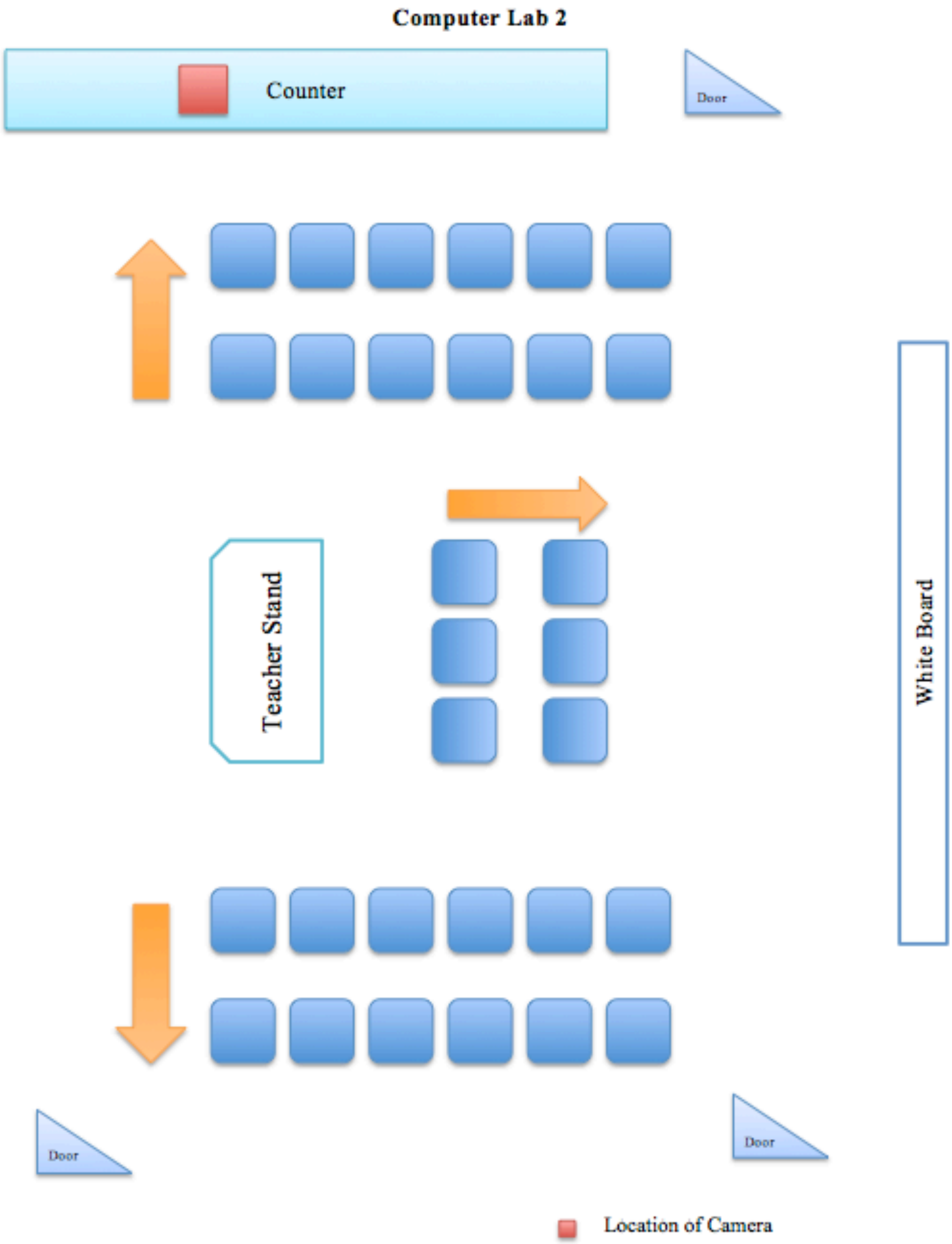
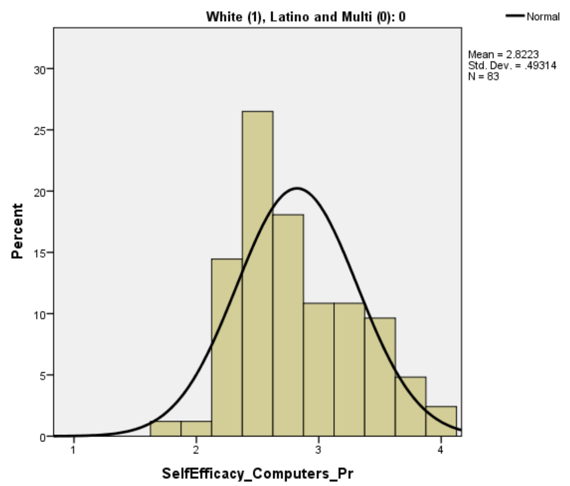
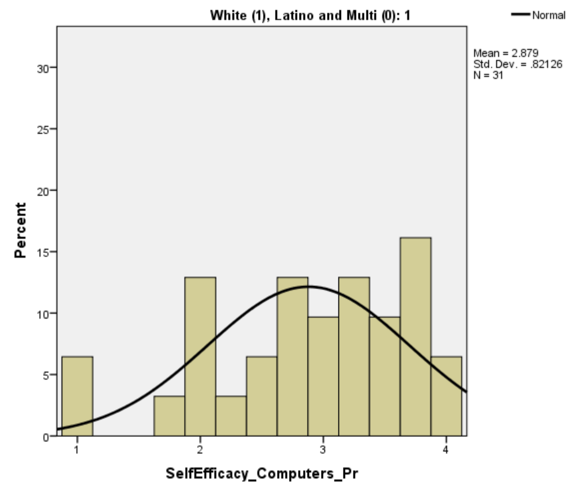


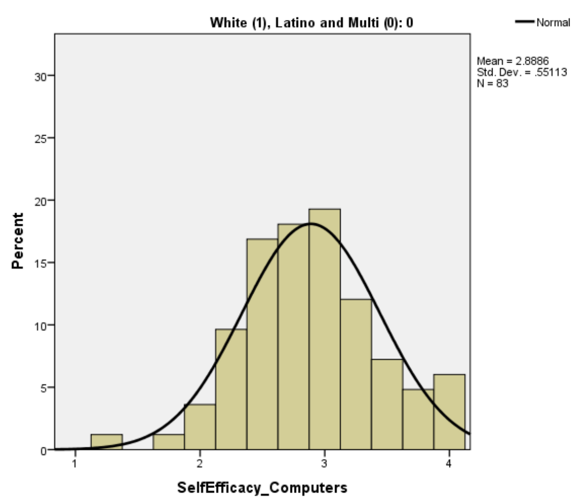
**Figure J.2 Lab 2 Diagram**

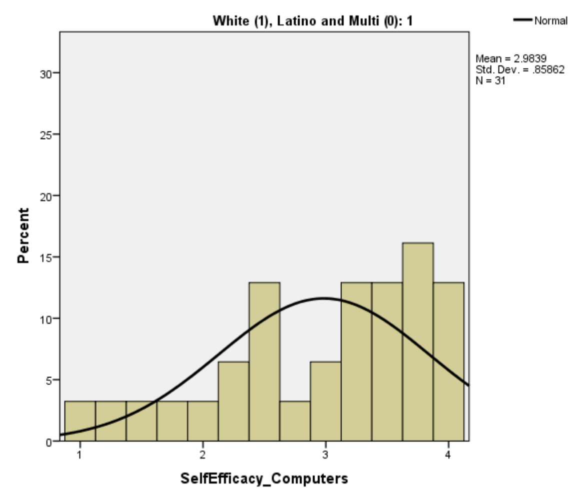


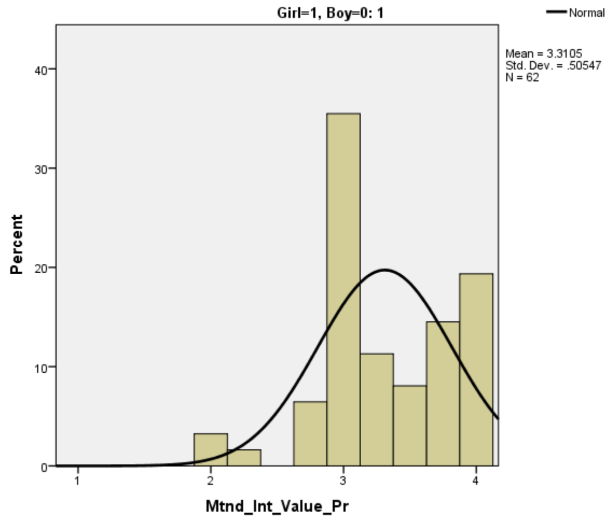
# Appendix K: Normal Distribution Graphs for ANCOVA tests.

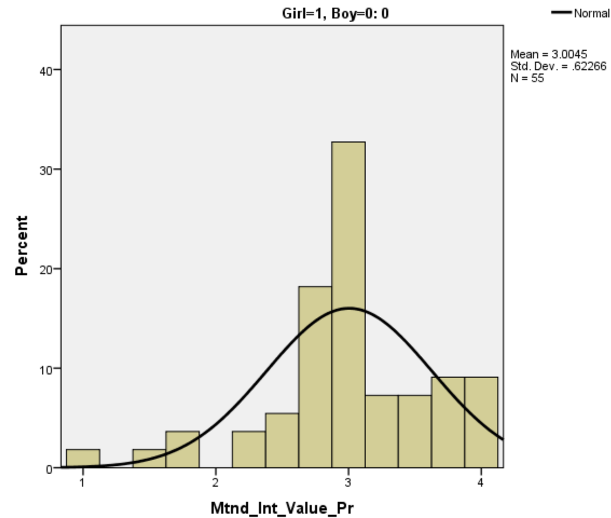


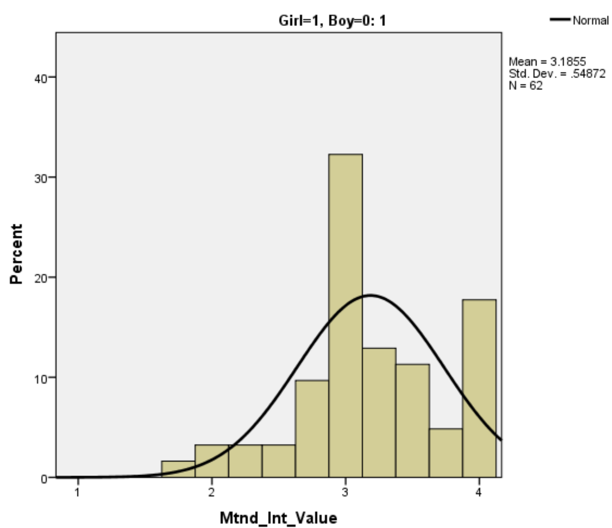



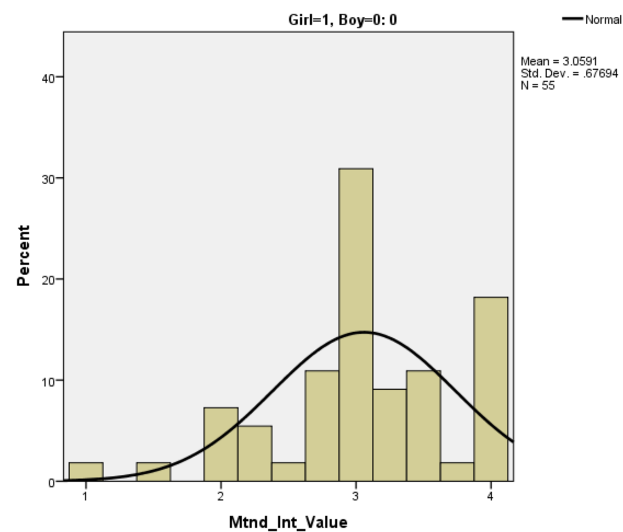




Girl=1, Boy=0: 1
Normal
Mean = 3.3105
Std. Dev. = .50547
N = 62
Percent
Mtnd_Int_Value_Pr


Girl=1, Boy=0: 0
Normal
Mean = 3.0045
Std. Dev. = .62266
N = 55
Percent
Mtnd_Int_Value_Pr


Girl=1, Boy=0: 1
Normal
Mean = 3.1855
Std. Dev. = .54872
N = 62
Percent
Mtnd_Int_Value


Girl=1, Boy=0: 0
Normal
Mean = 3.0591
Std. Dev. = .67694
N = 55
Percent
Mtnd_Int_Value

**Appendix L. Codebook for Coding Qualitative Data.**

| Construct/Category | Code | Description<br>Sources of Evidence | Example |
|---|---|---|---|
| A.<br>Self-Efficacy with Computers ✪ | A1.CT<br>Confident with technology | Presenting oneself as comfortable & confident with computers<br>• Surveys<br>• Interviews<br>• Observed behavior – limited | *Interview Example-*<br>Student states, "I've always loved computers. It's pretty much all I do at my house, get on the computer and play video games. I just like it." |
| | A4.LT<br>Lacking confidence with computers | Presenting oneself as lacking confidence or experience with technology, especially computers<br>• Surveys<br>• Interviews<br>• Observed behavior | Excessive hand raising can be a flag, especially when followed by utterances of lack of efficacy beyond mere lack of knowledge.<br><br>*Observed behavior example-*<br>When the teacher comes to help a student, student states that she never gets it right and just doesn't get computers. |
| | | | |
| B.<br>Self-Efficacy with Mathematics ✪ | B1.CM<br>Confident in math | Presenting oneself as comfortable & confident with mathematics<br>• Surveys<br>• Interviews<br>• Observed behavior - limited | *Interview Example 1-*<br>Q: *Do you like math?*<br>A: Yeah, It's my favorite subject. My favorite part [of this unit] was … collecting the data.<br><br>*Interview Example 2-*<br>Student states, "I usually help people, because in [math] class I'm the first one to be done most of the time." |
| | B4.LM<br>Lacking confidence in math | Presenting oneself as lacking confidence with mathematics<br>• Surveys<br>• Interviews | *Observed behavior example-*<br>Student talks aloud as she answers questions on the pre-survey. When she gets to the question "I am good at solving math problems" she states, "No, disagree. I am not" and the girl next to her says "yah right, ya know." |

| | | | |
|---|---|---|---|
| C.<br>Information Seeking | C1.WI<br>Wanting/seeking Information | Actively seeking information and knowledge (hand up in the air, walking up to teacher, etc.) from teacher, researcher or project assistant<br><br>• Observed behavior | *Observed behavior example-*<br>Student has her hand in the air frequently and for extended periods of time. She looks around trying to catch an adult's attention for her next question. |
| | C3.KI<br>Keeping Information | Keeping information obtained and knowledge to self after seeking out solutions or assistance from teacher, researcher or project assistants<br><br>• Observed behavior | *Observed behavior example-*<br>Student got a question answered about how to code the tree behavior so that the fire would spread appropriately. He did not share this information with his neighbor or get out of his seat to teach others. Student was often further along in the coding than his neighbor so the instruction just received may not be applicable to what his neighbor was working on. |
| | | | |
| D.<br>AgentSheets Experience Level | D1.ASN<br>AgentSheets Novice | Students with one year of AS experience (including current implementation or 6th grade Spanish)<br><br>• Interviews<br>• Surveys | *Interview example-*<br>When students tell what math class they had for 7th grade, I am able to classify them as AS novice or expert. One 7th grade teacher used AS and the other did not. Mrs. G's class did not use AS at all. |
| | D2.ASE<br>AgentSheets Expert | Students with two or three years of AS experience (including current implementation or 6th grade Spanish, and one or two more years in math classes)<br><br>• Interviews<br>• Surveys | *Interview example-*<br>When students tell what math class they had for 7th grade, I am able to classify them as AS novice or expert. One 7th grade teacher used AS and the other did not. Mr. S's class used AS for a statistics unit. |

| | | | |
|---|---|---|---|
| E.<br>Engagement | E1.P<br>Persistence<br><br>Independent work on computer<br><br>Independent math work | Student working independently on simulation and related activities<br><br>• Participation Logs<br>• Observed Behavior | Very little interaction with neighbors or other students in lab related to simulation or mathematics/statistics work.<br><br>*Example-*<br>Student focuses on his computer screen and works on his simulation. When he interacts with his neighbor it is unrelated to the simulation activity. He seeks help only from the adults in the lab, and does not offer suggestions for other students on the simulation project. |
| | E2.C<br>Collaboration | Student working collaboratively with one or more peers. Sharing information and knowledge with other students<br><br>Providing support for others when working on computers and solving computer problems or when working on related mathematics<br><br>Demonstrates level of importance of social aspect of learning for participant<br><br>• Participation Logs<br>• Observed Behavior | *Observed behavior examples-*<br>• Student gets one question answered, completes the changes to her simulation, and would often turn to her neighbor to make sure she knew how to do the same step.<br>• One student assists another student in finding the excel spreadsheet on the server, setting the forest density in the simulation properties, and shows students how to do multiple runs of the simulation and record the data.<br>• Student helps other students find the file containing the AgentSheets registration key and enter it in each day at the beginning of the period.<br><br>*Interview Example-*<br>Student states, "I tried to help the person next to me, but it was hard… I kept getting behind with setting them up" |
| | E3.H<br>Receiving teacher assistance | Student working with teacher or other adult helper (researcher, undergraduate assistant) on their project<br><br>• Participation Logs<br>• Observed Behavior | |

| | | | |
|---|---|---|---|
| E.<br>Engagement- cont. | E4.Q<br>Quitting or Shutting Down | Student showing signs of frustration but had not moved on to alternate activities<br><br>• Participation Logs<br>• Observed Behavior | **Note:** this code was not used much in this study. It was hard to catch this behavior before it went to off-task behavior. Codes E4.Q and E5.OT were collapsed into one category for analysis. |
| | E5.OT<br>Off-task | Student engaged in off-task behaviors such as talking with others about topics unrelated to unit activities, doing other schoolwork, playing math skill games on the computer, walking about lab, at another students computer, or out of the room<br><br>• Participation Logs<br>• Observed Behavior | A special note will be placed next to students who were given permission by the teacher to play math skill games because they had completed the simulation and related activities. |
| | E6.D<br>Done | Student has completed current section of project and is waiting until class catches up to begin next section of work.<br><br>• Participation Logs<br>• Observed Behavior | Example: Student is done designing and coding his simulation, but not yet doing data collection because data collection procedures not yet introduced to class. |

| | | | |
|---|---|---|---|
| | | | |
| F.<br>Future Pursuits ✪ | F1.FP<br>Future Intentions in school and career | Future scholarly work and careers identified by student as ones of interest or those in which they will likely engage.<br><br>Of particular focus are interests/intentions in STEM related schooling and careers<br>• Interviews<br>• Surveys | *Interview Example-*<br>Q: *What sort of careers are you thinking of doing when you are done with school?*<br>A: "I want to be part of the SWAT and State Patrol"<br>Q: *Are you considering careers that might include science, math, or technology?*<br>A: "Well, that does include science, because you've got to learn how to study the body, because if they get shot somewhere, you've got to know how to treat the person. And it does involve math, because in investigations, you learn how the bullet came, at what angle, at what time. Everything has math and science in it in some weird way." |
| | | | |
| G.<br>Interest | G1.TI<br>Triggered Situational Interest ✪<br>"Catch" | Initial interest sparked by the environment and externally supported<br>• Surveys<br>• Interviews | Interview examples:<br>Student – I tried it and "It's fun!"<br>Student 2 – It is not lame - I thought it would be |
| | G2.MIF<br>Maintained Situational Interest – Feeling ✪<br>"hold" because of liking material | Interested that is maintained beyond the initial spark because individual has personal liking for the subject matter<br>• Surveys<br>• Interviews | Interview examples:<br>Student wants to show brother her simulation at home<br>Student looks for the AS program at library<br>Student states that he is "Dabbling a little bit at my house with AS" |
| | G3.MIV<br>Maintained Situational Interest – Value ✪<br>"hold" because of valuing material | Interested that is maintained beyond the initial spark because individual believes the subject matter has current or future value in their lives<br>• Surveys | |
| | | | |

✪ One of the 6 main constructs from pre and post survey.

**Appendix M. Participation Logs**

**Figure M.1 Lab 1 Observation Log**

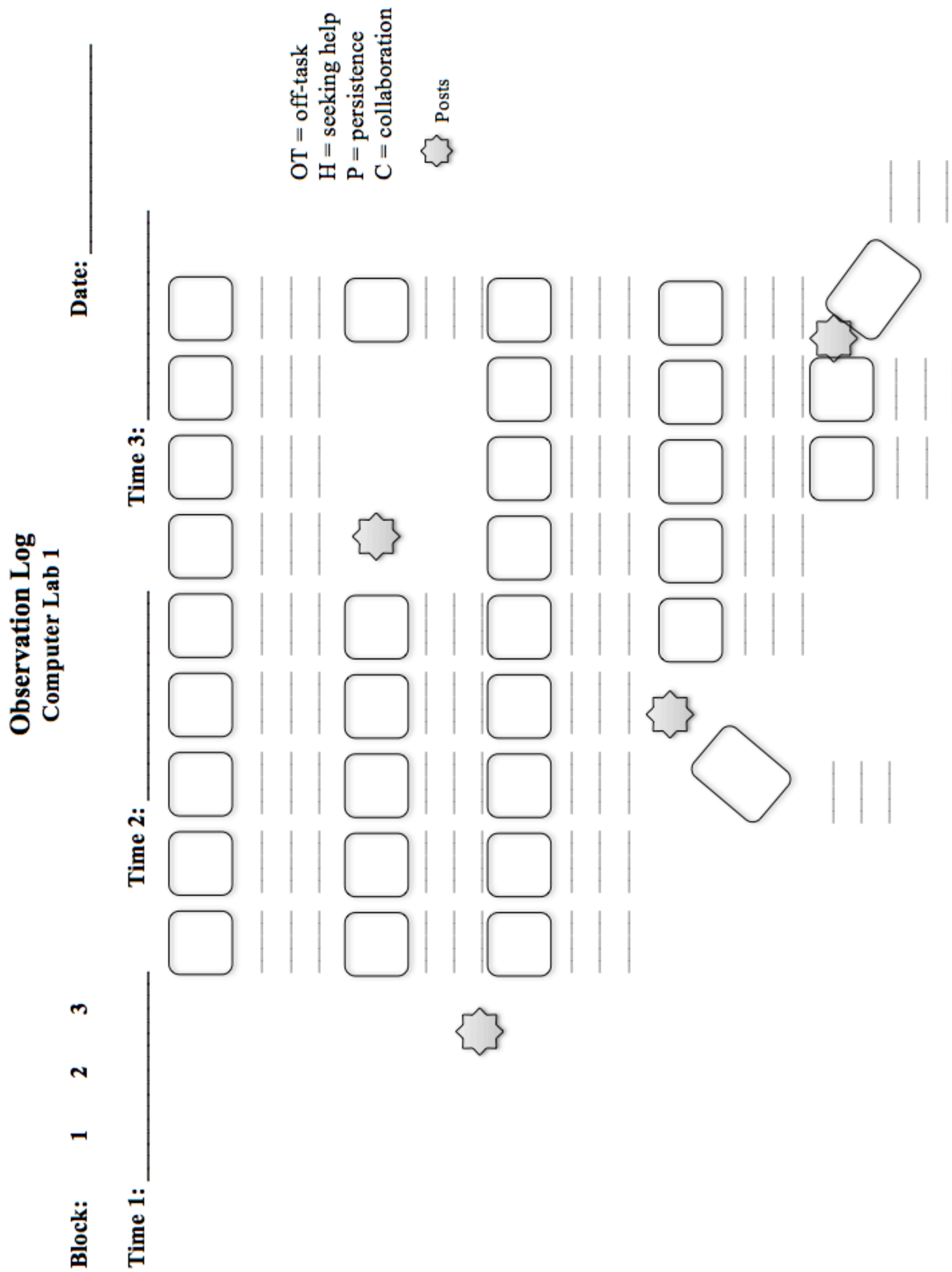
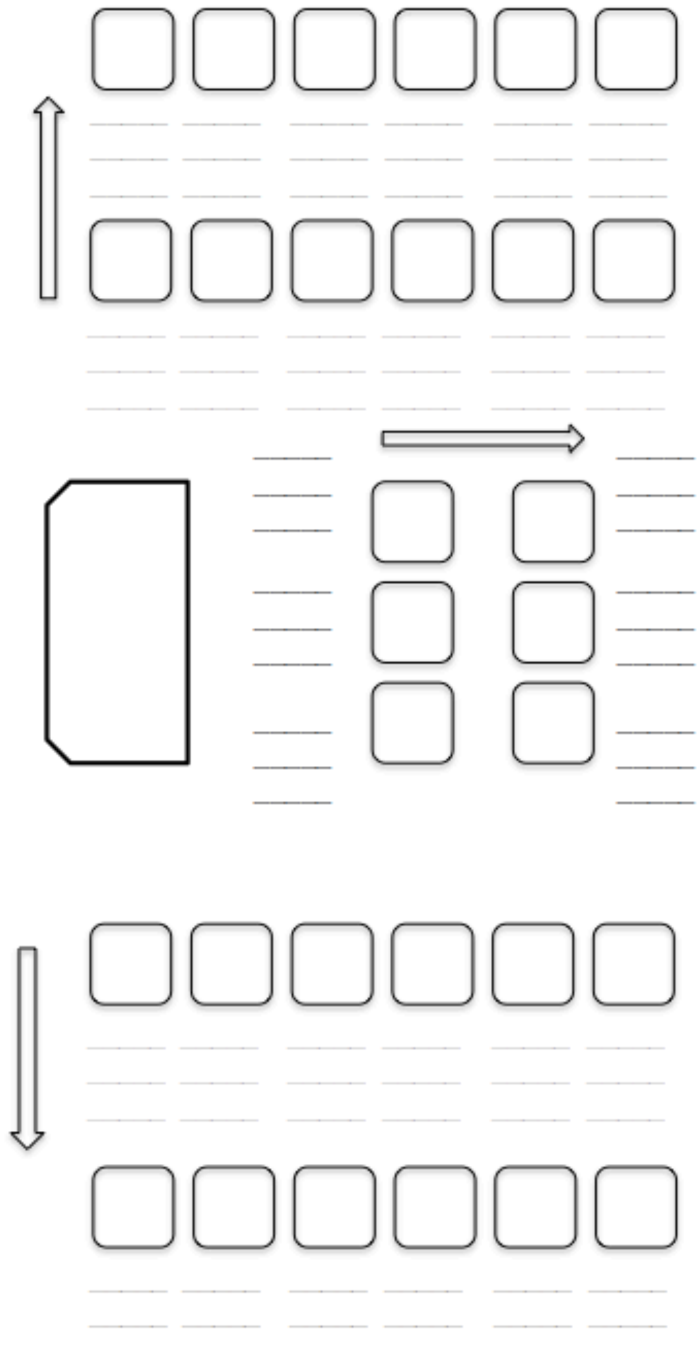


**Figure M.1 Lab 2 Observation Log**

## Observation Log
### Computer Lab 2

**Block:** **1** **2** **3** **Date:** ________________

**Time 1:** ________________ **Time 2:** ________________ **Time 3:** ________________



OT = off-task
H = seeking help
P = persistence
C = collaboration

**Appendix N. Challenges of Research Partnerships in K-12 Education**

One of the goals of the Scalable Game Design project was to implement technology unit is non-elective classes. This way, all students regardless of their social addresses would be exposed to the material. This works to disrupt the pattern of inequity based on self-selection and students' or counselors' pre-conceived notions of for whom technology classes are "appropriate." When all students are enrolled, regardless of gender, race, previous experience with computers, or socioeconomic status, the barriers to entry that have nothing to do with aptitude or even initial interest fall away.

In this project, the Simulation in Statistics units were implemented in mathematics classes, which are required courses for all students at North Middle School. This allowed for all students to have access to the material, but also came with additional scrutiny from the district and school level administration. Mathematics is a critical area for most schools when considering the accountability structures imposed by state and federal regulating agencies. When the school or district is not performing well according to these mandates, the pressure from these policies is even greater. This was the case at North Middle School, and other schools in the school district.

The main concern for the Superintendent and school district personnel was reaching Adequate Yearly Progress (AYP) as determined by *No Child Left Behind* (NCLB) legislation. As North Middle School had missed their AYP requirements for the 4 prior years, they were required to engage in "corrective action." Since they were not the only school failing to meet AYP, the entire district was close to becoming "restructured." This district had high student mobility and absentee rates, so the NCLB AYP requirement of testing 95% of their students posed a challenge. However, if they did not meet AYP, primarily by increasing standardized test scores and insuring that 95% of their students were tested, most of the district personnel would be replaced, including the Superintendent, Principals, and many teachers.

The Superintendent did have a special interest in technology though. He had earned his master's degree in computer science, and wanted to ensure that the students in his district were technologically skilled. To emphasize this district goal, he set policy that all classes contain the use of technology as it related to each individual subject. He wanted technology to be an integral part of each content class. Because we were interested in implementing the project in core content areas, this seemed to support the district goal of technology and content material integration.

A Spanish teacher originally introduced the AgentSheets software to North Middle School. For that year, the district personnel, including the Principal of North Middle School, did not scrutinize the value of the program and related units. Spanish was a non-tested subject (something that is slated to change with the implementation of Colorado State Senate Bill 191), so there seemed to be more flexibility in the tools and resources allowed in these classes.

However, before we began implementing the units in mathematics classes, we had several meetings with the Principal and the teachers to explain what the program entailed and its expected impact on "regular" mathematics content. The project team spent a considerable amount of time educating and convincing school district personnel of its merits. The Principal wanted assurances that the amount of instructional time devoted to the project would not take away from the focus on the standards that would be tested on the Colorado Student Assessment Program (CSAP), Colorado state's accountability measure. The message was that any time spent should be commensurate with the likely positive outcome in CSAP testing. After receiving the approval from the Principal and Assistant Principal, we then were asked to present the project information to the entire staff at an all-school staff meeting.

During the pilot study year, we developed and implemented the Simulations in Statistics (Sim-Stat) units. We designed the units based on the Colorado Academic Standards, and the instructional sequences for each of the mathematics courses at NMS. The units addressed the statistics and probability standards at the corresponding 6th, 7th and 8th grade levels and aligned with the text book series used by the district, *Connected Mathematics 2*™. The Sim-Stat units were iteratively implemented and updated through a design research process.

Project team members also met with the Principal during implementation. She was very enthusiastic about the project and had even credited participation in this project as one of the considerations that earned North Middle School national recognition. She assured us that we would be able to continue to implement the project the following school year. The summer following the pilot study year, four math teachers from North Middle School attended the Scalable Game Design Summer Institute. Three of these teachers presented information about the units they had implemented the previous school year to the entire group of attendees. Additionally, as part of the summer institute, all teachers agree to implement two one-week units the following school year for an additional stipend. The teachers seemed excited to use the new content learned in their summer training and we were confident that the project would be moving ahead without further ado.

This was not to be the case. The Principal from the pilot study year accepted a position in another school district, and a new Principal for NMS was hired. When the teachers returned after their summer break, the new Principal asked them about the Scalable Game Design / Simulations in Statistics project. After getting a few details about the AgentSheets software, she then asked them if they would be willing to teach AgentSheets as a semester-long elective class. The teachers hesitated. The principal interpreted this as the teachers not wanted to participate in the project at all, but were being pressured to participate. The principal then contacted the Superintendent, who requested an August meeting with the project team. The project was in jeopardy of not being allowed to continue.

An AgentSheets representative and myself and another individual from University of Colorado Boulder, met at the district office with the new Principal, the Superintendent, the Principal of another Middle School (who had attended the Scalable Game Design summer institute the first year), and the Tech Support Specialist. The Tech Specialist and the other Principal were in support of allowing AgentSheets in the district. They provided testimonial to how they had seen the program working well with students in classes, and how this program reached students that had not always been successful in the past. The Tech Specialist even presented a PowerPoint presentation about the project with some screen shots for the superintendent and new principal to see. This was an unexpected show of support and greatly appreciated. Because it came from district employees, rather than an external vendor, it seemed to be well received. Although it was a bit tense at first, the meeting went well overall. We spent a lot of time clearing up misconceptions and educating the Principal and Superintendent about the program and its ties to existing curriculum and integration of the math standards.

New Principal explained that she hadn't wanted students to use AgentSheets because, based on its name, she thought it was a series of worksheets. She also explained that when she asked her teachers if they would teach AgentSheets as an elective, the teachers did not feel comfortable with this. She did not understand that the units were integrated within math content and had not been taught as a stand-alone. She also did not realize that the project provided support personnel during classroom implementation. She interpreted their hesitation to teach this as a stand-alone class as an outside vendor wanting teachers to teach something unrelated and not supported by the teachers. By the end of the meeting she had a better understanding of the units, their relation to tested math standards, and the support that would be provided during the implementation. She seemed comfortable with allowing the project to continue. The Superintendent remained concerned about the school's data and reaching AYP. In light of these very real and immediate pressures, the Superintendent requested a second meeting where we would present data to show progress of the project thus far and how this unit would relate to test scores and performance on mathematics assessments.

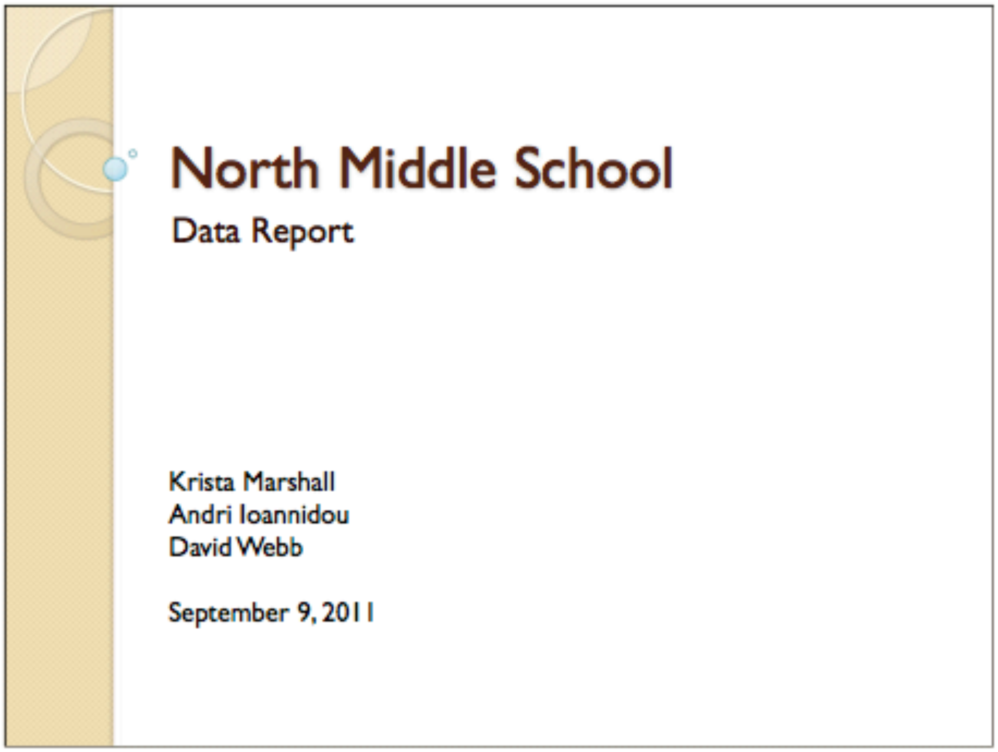
Prior to our second meeting, set for one week later, I analyzed the pilot project data. This included student demographic data, pre and post-surveys, and pre and post math content assessments. I crafted a data presentation with summary statistics and quotes from students (select slides are at the end of this appendix) and presented it in the meeting at the middle school. SGD project personnel, the Superintendent, the Principal, and two NMS teachers were in attendance for the data presentation. The tone of the second meeting was completely different. Apparently we had provided adequate answers to the most pressing questions at the first meeting, and this gathering was more relaxed and collegial, rather than inquisition-like. The Superintendent and the Principal gave the official go-ahead for the project and at this meeting the Principal signed the District Approval Letter that was submitted to the Institutional Review Board.

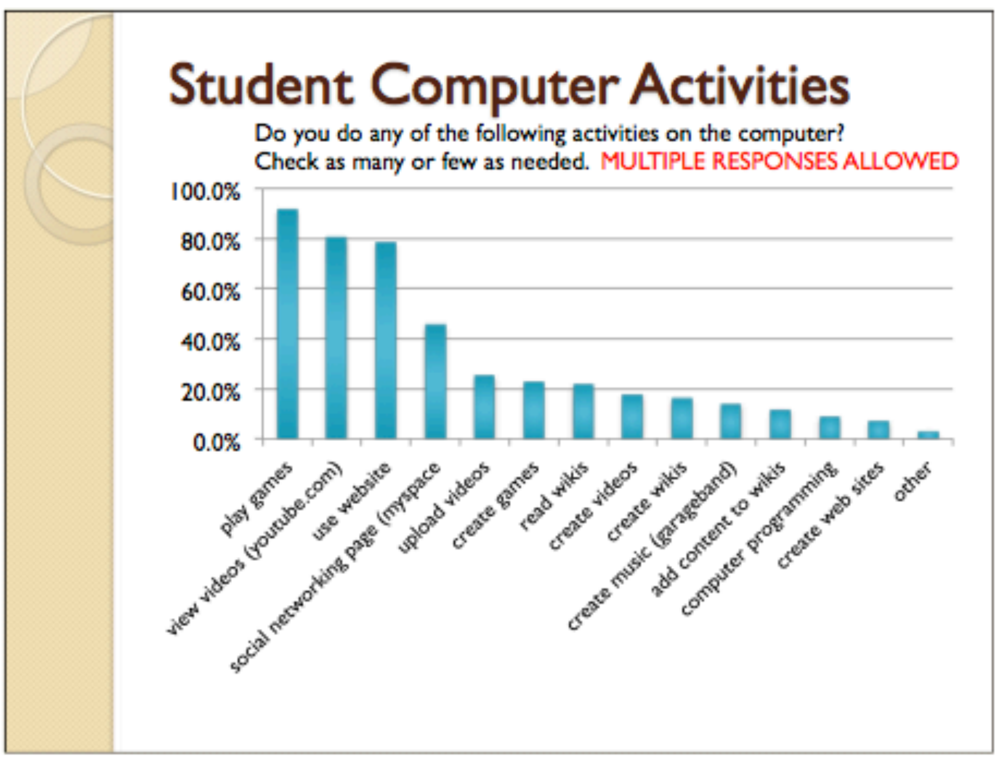
With increased pressures mounting on school districts across the country, we will likely find it ever more difficult to conduct research projects in K-12 educational settings. With the passage of Colorado State Senate Bill 191, for example, which requires adequate growth data for all grades and subjects, it is likely that even in elective classes like Spanish and Technology, the responsibility to prove impact on standardized test scores will fall to education researchers.

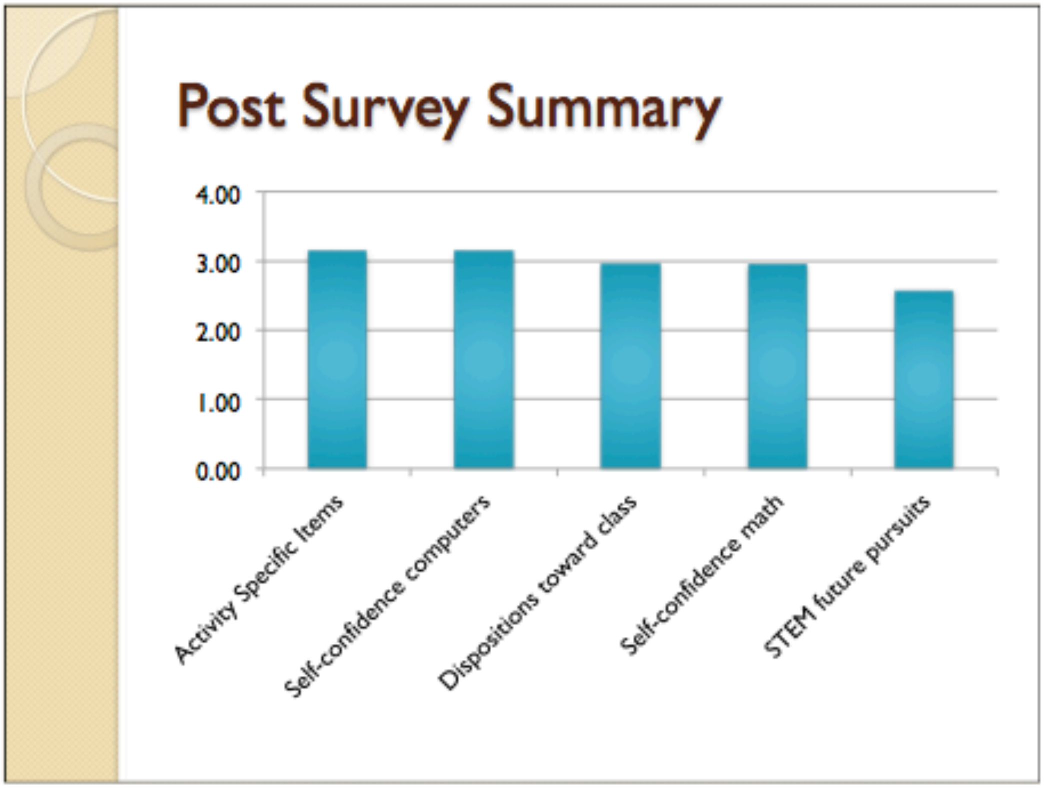
I kept in contact with the teachers from North Middle School the year after the project implementation year to see what the next school year would entail as far as continued Sim-Stat or other AgentSheets project work. The summer after the implementation year, no teachers from North Middle School attended. The Scalable Game Design project had ended and the project team had shifted into the CT4TC (Computational Thinking for Teaching Computing) project with a larger emphasis on using the newly released AgentCubes program. The project team also gave priority to teachers new to the project when determining registration acceptance. During the school year following implementation, the teachers reported that the district had reversed its recommendation that technology only be incorporated into content classes and not taught in stand-alone courses. According to the teachers, having all students involved in the Sim-Stat/ Scalable Game Design project had highlighted the students' lack of basic computing skills. Many students had difficulties with terminology and general navigation on the computer. For example, it took a great deal of support for students to understand what a uniform resource locator (URL) is and how to type in a specific URL to go to the pre-survey. This supported the case that the Tech Support person had been making for general technology classes at the middle school level. During the school year following this study, North Middle School offered elective technology classes for the first time in many years. The classes were held during the same time periods as mathematics classes. As a result, the computer labs were not readily available for math classes to use, and the math teachers were not able to implement AgentSheets based Sim-Stats units to the same extent.

While it is encouraging that there is now a larger emphasis on technology at North Middle School, the new structure of technology classes was disappointing in several respects. First, technology education was now in elective classes. I do not have enrollment data, but teachers reported that the gender split became unbalanced with many more boys than girls electing to take the technology classes. Our emphasis on enrolling all students to disrupt the inequity of self-selection had been overturned, and with it the likelihood of exposing and shifting interest states for a larger percentage of girls and students of color in STEM content and related careers. Second, there was not cross-curricular focus. During the implementation of the Sim-Stat units, we had direct ties between technology, mathematics, and science. These connections were no longer part of the curriculum in the elective classes. Technology was taught in isolation with little reference or application to what was going on in other classes students were taking. Third, the teachers who had participated in the summer institutes and knew the AgentSheets software and related curriculum the best were not teaching technology to the same extent. These teachers understood the importance of including computational thinking patterns into the units, and aligning to content standards. It is unclear if the new technology classes will continue to use the AgentSheets software and/or the supporting curriculum.

**Appendix N.1 North Middle School Data Report.**






## Matched Pre/Post Statistics Content Test Results

- Pre-Test Mean = 5.6 of 25 (22.3%)
  - SD = 3.83
- Post-Test Mean = 19.3 of 25 (77.2%)
  - SD = 3.23
- Mean Post minus Pre = 13.7 (54.8% increase)
- 95% Confidence Interval: 12.58 to 14.72
- Paired two-tailed t test $p < .0001$
  - Very statistically significant difference
- N=46, three blocks from same teacher

**Appendix O. Additional Interview Results.**

**Students' Metacognitive Reflections**

For some students, sharing their opinions of a wider perspective about the units, and about mathematics and technology learning in general, was a natural extension of the interview questions. Other students needed to be asked directly to do this kind of metacognitive work.

Students were asked to reflect on the design and development process they went through in the Simulation in Statistics units. They were asked questions about what they would do differently if they created the simulation again (see Appendix O), what they learned while engaging in the project, and were asked to imagine what they would do in a math class using technology if they were the teacher of the class. The ability to ascertain your current level of understanding and reflect on your performance is referred to as "metacognition" (National Research Council, 2000). Students' metacognition is not only interesting from a research perspective, but it is an essential skill to teach students. The practice of considering the boundaries of current knowledge and then identifying new learning that needs to take place is important for all students.

Students identified the availability of online resources to assist them in their work as one component that helped them expand the boundaries of their current knowledge. Several students commented on tutorial use even though this was not a formal interview question. The semi-structured nature of the interviews allowed for this topic to be explored while the interviews were under way.

***"What would you do differently?"***

When asked what they would do differently if they redid the project, most students stated that they would change the appearance, not the functionality, of the simulation. Below are some representative comments from students regarding the changes they would make in appearance:

- "I would put the ground different … it just looks pink and blue. I don't think there's a ground like that. I would rather do it green."
- "I'd make the background different and the trees different."
- "I'd [make] smaller character thingies and then a bigger, like, worksheet, so I can make more trees, more fire."
- "I would … change the colors, change the picture."

The willingness to modify the appearance and add or delete agents could be attributed to self-efficacy beliefs. Perhaps students felt more comfortable with this aspect of the simulation design and creation than they did with programming the behaviors. One student reasoned that he would not change the behaviors because "it would have to be the same so it could work out again", believing that if he modified the behaviors the simulation would not work. This could be because of limited understanding of how to change the behaviors in a way that would be interesting for the project. Lower self-efficacy or understanding of the behavior programming could lead to students' reluctance to change this aspect of their simulations.

One student mentioned that he would vary some programmed behaviors to introduce chance of catching fire as a manipulable variable, so that the person running the simulation could enter in different probability of the fire spreading instead of leaving this a constant. With these modifications then, the trees "might or might not catch on fire." He went on to explain how this would impact the simulation, "If it [the probability] was higher, the trees would catch on fire faster. If it was lower, it would take a while, or maybe it wouldn't (catch on fire)." Through this dialog, the student demonstrated comfort with modifying the behaviors in the simulation and understanding of the underlying mathematical concepts supporting the simulation properties.

Though some students expressed interest in modifying the programmed behaviors, I thought this would be a more common response. In particular, I thought someone would have mentioned that they would add wind direction and/or speed or moisture level to the simulation as we had discussed these concepts the first day of the unit. Perhaps this illuminates a problem with the "sage on the stage" approach to the unit introduction, or the limited amount of time students spent in the computer lab to explore extensions.

Perhaps for the same reasons, students held some misconceptions about key aspects of the simulation design. For example, several students expressed misconceptions about the placement of trees on the initial worksheet as being important. The following statements illustrate this misconception.

- "[I would] set up the trees, because they were all, like, together, so maybe that's why all of them got kind of burned."
- "I would place less [*sic*] trees than I did in the first time to see the difference."
- "[I would] probably change the trees and the amount of trees."

In reality, the initial number and placement of the trees on the worksheet was of no consequence; when the class gathered data by running their simulations, the simulation generated a new forest each time based on the density set in the simulation properties. When the forest was regenerated, the starting worksheet was overwritten and new trees were placed on the worksheet automatically based on the percent density entered. The initial drawing of the forest did not matter to the functionality of the simulation.

Some students acknowledged that they were aware they had some misconceptions and areas that they did not understand as well. These students shared that if they could do something differently in the units, they would pay attention more to the direct instruction part of the lesson or the tutorial to make the programming go more smoothly:

- "I would actually pay attention more this time."
- "I would probably, like, pay more attention so I wouldn't have to ask too many questions and could make my forest better."
- "I would actually, like, go off of the [tutorial] in the first place instead of trying to figure it out on my own and then looking back at it."

**Student Learning**

Students not only learned about how to use the AgentSheets software, but they used these skills to learn mathematics content and tied this learning to larger life lessons. Students were asked to step back from the specifics of their projects, and describe what learning had taken place for them both in general and in the area of mathematics and statistics.

***What Students Learned in General***

In the interviews, students were asked, "What do you think you learned from creating the simulation?" Student responses varied considerably. Some were related to specific properties of the simulation created by the students such as the meaning of density in this context or the relationship between tree density and percent of the forest burnt during a simulation run. While others offered tips for programing and running simulations created with AgentSheets. For example one student responded, "It's better when [the simulation] goes slow, 'cause you can see the trees when they go up. You don't want to do multiple layers, or else it messes it up. And don't put your controller on top of the ground or a tree." Still other students described learning that had more to do with the general benefits of using simulations to test phenomena not easily or not possible to test in real life. A female Latina student related her learning from two years of participation in the Sim-Stat units; she said she learned “why some people would use the simulations for real-life things. Like, last year we did the virus to see how viruses are spread, and this year we did forest fires, and it helped us in the real life without going and burning or getting a bunch of people sick.” The benefits of using simulations to explore natural phenomena were discussed in the unit introductions. Computer simulations are useful when it is impossible or unethical to run the experiment in real life.

While the question was often interpreted as specifically relating to the simulation activities or use of the AgentSheets software, some students shared general learning of life lessons. Some student responses from this category were:

- “I learned that it’s always good to have a controlled fire, that if it’s not quite controlled, it could burn down an entire forest.”
- “I learned, like, that if you have a house in the forest, you don’t have to cut down all of the trees like I thought you would have to.”
- “I learned to be careful with the forest, to not try and make fires, because if there’s a lot of trees, a lot of trees will get burned, and there might be houses in the forest that might also get burned, and they might not have a way out.”

And another student shared, “I learned that things could be complicated, but if you get help, then it’s easier”; this is a life lesson we would all do better to remember.

***What Students Learned about Statistics and Mathematics***

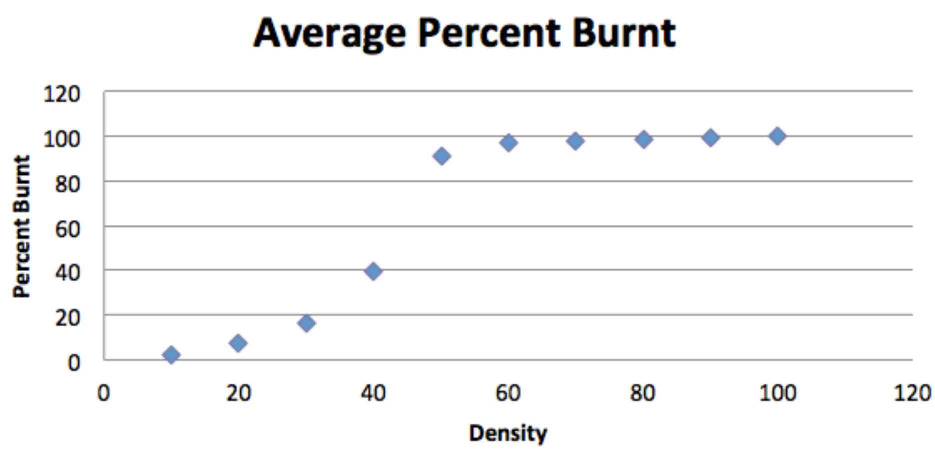
One of the questions asked in the interviews was, “What do you think you learned about statistics by doing this unit?” The introduction to the unit seemed set the stage for the learning of mathematics. In an early pilot study, the principal did a classroom visit during one of the units being implemented in the 7th grade classes. She asked a student to explain what math they were using in this unit. One student replied that she didn't know, another guessed, "counting?" Overhearing this conversation impressed on both the teachers and myself that an introduction to the unit, where we would explicitly connect the context for the simulation and the computer lab time to mathematical concepts and statistical tools being learned, was critical for student understanding. We then developed and incorporated the Prezi introductions for each of the units.

As we see in this section, with the inclusion of these new unit introductions, the students were clearer about the integral nature of the mathematics to project completion, especially the data analysis section. In response to the above question, most students described procedural mathematics not conceptual understandings. In other words, students tended to give step-by-step directions for some mathematical task rather than describing a mathematical concept they had mastered. These procedural lessons learned fell into three main categories: data sampling, linearity including modeling a line of best fit, and fundamental math skills.

Students talked about learning about data sampling by describing how they ran the simulation five times for each density in increments of ten from 10 percent to 100 percent. Then they used these to find the average percent burnt at each density level. When asked what the benefit of using the mean was, one student responded, "The average gives you how many burnt trees that there usually are at the desired density number." Though the students all followed the same procedure, each student ran their simulation independently, and therefore students had different values to average. Several students mentioned that they appreciated that each student had unique results; one student stated, "That's what I liked about it, because it's not the same every time, it's always different and it always resets itself at random. Everybody's was different." This uniqueness referred to the percent burnt values being averaged, not the graphs of the averaged data. These graphs turned out very similar across the class, even though the students started with different values from their simulation runs.

As a part of the data analysis for the unit the students were asked about the linearity of the data resulting from the simulation. Most graphs looked similar to Figure O.1.

**Figure O.1 Sample Graph from Student Data Analysis Spreadsheet**




The majority of the students described their data as being linear, well represented by a line. The line that they fit to the data was described as having a steep positive slope and many students were able to describe what that slope meant in this context. As one student stated, a positive slope meant, "more trees burnt every time the density went up." Other students felt that the data was not well represented by a line. One student elaborated, "Well, we had to find the line of best fit, but there was a whole bunch of outliers, and it was really hard to find it. It wasn't linear, at all." Though the graphs of the forest fire simulation results were essentially non-linear, the teachers asked the students to estimate a line of best fit to practice this mathematical procedure in the context of the simulation. We decided that linear estimation could provide a useful lens for making sense of the raw data and predictions using this data.

Other students discussed fundamental math skills that they learned about by participating in this unit. Students described learning about calculating percentages, graphing points on a coordinate plane, and computing the mean. Some students commented on the benefit of using technology to help with these tasks. In particular, students mentioned that they enjoyed using spreadsheet software to display and calculate aggregated results. For several students, this was the first time that they had used spreadsheet software for math classwork.

There were some mathematical misconceptions that became evident from the students responses as well. These fell primarily into the categories of sampling and linearity. One student shared a misconception regarding sampling; he said that the reason for running each of the densities repeatedly was to "check your work" and to see if the graph was linear. He seemed to misunderstand the need for multiple data points to create a more representative sample where the one point plotted was an average of many simulation runs rather than a single data point.

As an example of a student misconception regarding linearity, a student explained that she thought her graph was non-linear because of the number of trees she had originally placed on her simulation worksheet (prior to regeneration of the forest). She said that other students had linear graphs because they had fewer trees. As mentioned previously, the initial number of trees did not affect the simulation output, including the shape of the graph. A few students were still unclear about the purpose of fitting a line of best fit. Some did not see this as a decision about whether or not the data is well represented by a line, but more a check of their work. One student responded,

> I think the line of best-fit shows whether the data is accurate. Like, if there isn't a line of best fit, you might want to check and say, 'Oh, maybe I did something wrong,' because there most of the time is a line of best fit, whether it covers two

> points or whatever, but if you don't have a line of best fit at all, I don't think you did it right.

The assumption being we are learning about linear data, so all data must be linear in this section. If my data is not linear, then I have calculated something incorrectly. This speaks to the way that we often teach mathematics, in chunks of related material. Students are not often asked to make decisions of whether or not a newly learned skill is applicable to the given problem. It is a given that they are just to repeatedly practice the same skill and it will always apply to the problems in this section of the text book. This brings us to another area that we asked for input from interviewees, practices in math class in general.

**What if you had your own math class?**

Beyond just asking students to reflect on their learning, students were asked to make recommendations for subsequent implementations of the Sim-Stat units. This was accomplished by asking students to imagine that they were a math teacher and they were going to use technology in their classes, and to talk about what they would do. Many of the students said that they would do just the same as their current class, use AgentSheets, come to the lab for a couple weeks a year, have their students create simulations, etc. Grace liked this unit. She said, "I'd probably do this, the forest fire simulation, do the research thing, too, not really research, but the data collection, 'cause that gets kids engaged, like, it got me engaged. I was looking forward to coming into the class, 'cause it's really cool, you get to do your own thing. You have help. You didn't have to wait for people to tell you what to do, like in a normal classroom. You know how you're learning everything at the same pace. You got to go at your own pace and do everything however you wanted to do it." However some students suggested changes to this schedule.

The most common suggestions were to have their students do games instead of, or in addition to, simulations and to come to the lab more frequently for AgentSheets use. Erin said she would have her students come to the lab more often "Cause it gets *my* [laughs] students a time to get up for class and not sit down a lot and learn and do bookwork, and it gets them time to be on the computer. Just no Facebook." Amanda said that she would "involve it more into everyday math class. Like, not just forest fire simulations or the games that we do have, but more simulations like, what would happen if you dropped a bomb in water? More unrealistic, but mathematical things." Maddie would use AgentSheets for both games and simulations with her students, "Games are fun, but it still involves math in order to do it, and simulations are really educational and you can learn from it, and it's also fun." Several students suggested increasing time in the lab and the creation of both games and simulations in their "own" math class.

Students at North Middle School occasionally played math skills games on the computer as a part of math class. Pablo shared that he thought some of the math skills games they used in the lab were boring and "there's some games on there that aren't even related to math." Instead, he said, with his students he would have them build games and simulations using AgentSheets because he thought it was more related to math. He gave an example of how the forest fire simulation made it easier for him to understand percentage. In referring to forest density, he said "the higher something's gonna be, the more percent it's gonna be, the less, the less percentage. So that's why it made it easier for me to understand." Veronica said that she would allow her students to "pick their own simulation to do and how to do it, but it'd take more work for them." A few students, like Veronica, suggested allowing "their students" a choice of what project to create. This lead me to believe that they would have liked this option for themselves during the Sim-Stat unit or in a subsequent unit in the computer lab using the AgentSheets software.

Students were also asked a survey question about what technology they would use in a math class that they develop. They were asked, "If you could design a math class that uses computers, what would you like to do?" This was a slightly different question than the one asked in the interview where they imagined that they were a math teacher and told about what they would have their classes do when using technology. There were 118 student responses to the online survey question. Overall, students seemed satisfied with using AgentSheets as the software of choice for their "own" math classes both in the interviews and in the survey responses. In the survey approximately 70% of the student responses were to keep the status quo: same schedule, same activities, same software with a focus on student design and creation of games and/or simulations.

Twenty percent suggested changing the approach in some way: 13% made suggestions for including more computer use content such as teaching students about how to do web searches for information, keyboarding, and the inclusion of other computer applications such as website creation, communication software such as video chatting and Facebook, and Photoshop, and 7% made suggestions for modifying the time spent in the lab, usually asking for an increase amount of time for their "own" class.

No one interviewed suggested that they would not take their classes to the lab at all, though 12 students (approximately 10%) responded in a way that indicated that they were not interested in participating in the thought experiment this question posed. These students typed responses to the survey question such as, "IDK", "I have no idea", or "nothing."

The responses could have been heavily weighted to maintaining the status quo because students had had limited experiences in the computer lab. They had not used other game authoring software, and did not go to the computer lab often in math except for standardized testing. On these days, if they finished their testing early, students used "Hooda Math" (http://hoodamath.com/) an online math skills practice site. In other classes, students came to the lab to use word processing and presentation programs. In this way perhaps the question was a bit unfair, what else would they suggest if this is the only software they were familiar with? On the other hand, perhaps the large response to maintain the current schedule, software, and Sim-Stat unit layout was because it was working, and students had enjoyed and valued the experience.