

**Science and Mathematics Education Centre**

**A Comparison of One-to-One and Two-to-One computing in  
Elementary Mathematics Classrooms: Students' Perceptions of Their  
Learning Environment, Attitudes towards Mathematics and Their  
Mathematics Achievement**

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**This thesis is presented for the Degree of  
Doctor of Philosophy  
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## **Declaration**

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief, this thesis contains no material previously published by any person except where due acknowledgement has been made.

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

## ABSTRACT

The main purpose of the research was to compare the learning environments, attitudes towards mathematics, and achievement in mathematics of fourth and fifth grade students who were learning mathematics in 1:1 and 2:1 computing learning environments and determine whether or not 2:1 computing initiatives foster a positive learning environment, improve student attitudes towards mathematics, and increase student achievement in mathematics. All of the students who participated in the study were taught in either a 2:1 or 1:1 computing environment from December to the end of the school year in June.

Mixed methods were used in this study in an attempt to fully describe the possible changes in the learning environment. A pretest and posttest design was used to obtain quantitative information from two surveys, namely the What Is Happening In this Class? Questionnaire (WIHIC) (Aldridge, Fraser, & Huang, 1999) and the Test of Mathematics-Related Attitudes (TOMRA), which is based upon the Test of Science-Related Attitudes (TOSRA; Fraser, 1981), and the New York State Mathematics Assessments (NYSE). Qualitative information was collected through direct observation and natural conversations with teachers and students. One hundred twenty-four students were included in this study; 89 were fourth and fifth graders studying in a 2:1 computing environment, and 35 were fifth graders studying in a 1:1 computing environment.

In order to control for pretest scores, multivariate MANCOVA were conducted for the set of WIHIC and TOMRA scales. When these multivariate tests yielded significant overall differences, the univariate ANCOVA was interpreted separately for each WIHIC and TOMRA scale. Analysis of the WIHIC scores revealed that the 2:1 group perceived significantly higher classroom Involvement and Investigation than did the 1:1 group at the time of posttesting when pretest differences were controlled statistically. In addition, when the differences between the pre-posttest means for the 2:1 and 1:1 computing environments were compared in the areas of Involvement and Investigation, the means for the 2:1 computing increased from the pretest to the posttest, while the means for 1:1 computing decreased for each of these scales. The differences between 2:1 and 1:1 computing environments were not statistically

significant for any of the three scales of the TOMRA, when pretest differences were controlled statistically. Although there was no overall consistent pattern of correlations, the data showed statistically significant correlations between the WIHIC scales and the TOMRA scales for both the 2:1 and 1:1 computing environments; in particular, there were statistically significant positive correlations for the 2:1 computing group between Task Orientation and the three scales of TOMRA, Attitudes towards Mathematics Inquiry, Adoption of Mathematics Attitudes, and Enjoyment of Mathematics, that were not significant for the 1:1 computing group.

The observational and conversational data provided limited support for the quantitative findings. In particular, students learning in the 2:1 computing environment shared that they were part of a supportive community of mathematical learners alongside their teachers. Students were observed actively working together using the tablets to investigate and problem solve real world questions. When the students arrived at the answers, they were eager to report and justify them to the rest of the class.

Unfortunately any links to achievement were marred by questions regarding the validity of the New York State Mathematics Assessments after they were administered. Although there were statistically significant correlations between the Student Cohesiveness and Involvement of the WIHIC and the NYSE with the 1:1 computing learning environment, it is difficult to decipher whether or not these were due to the interventions or the flaws in the examinations. Further studies, using more reliable assessments, would be needed to make this determination.

Overall, this research study showed that 2:1 computing may be a viable alternative to 1:1 computing in elementary mathematics classrooms. The 2:1 computing learning environment was found to have statistically significant positive effects in both the fourth and fifth grade mathematics classrooms in the areas of involvement and investigation, as compared to the 1:1 computing learning environment.

## DEDICATION

I wish to thank many people for their help, love, and support through this long journey. First and foremost, I would like to thank my wife Kaitlyn and my two children Gerard and Reagan, collectively you are the driving force in my life and motivate me to be a better person and focus on what is important. I know that the time and financial commitment has not been easy and I thank each of you for your personal sacrifices. Second, I would like to thank my mentor, Professor David Treagust, without your guidance and infinite patience, this would never have seen completion. Third, I would like to thank Professor Barry Fraser, Dr. Chandra Chandrasegaran, and the rest of the Curtin staff who supported my studies. Fourth, I would like to thank all of the members of the Lynbrook Board of Education, Jill Robinson, Dr. Paul Lynch, the rest of the Lynbrook staff, and the students who took part in my study. Your generosity is most appreciated. Finally, I would like to thank God and my parents for providing me the support and nurturing from an early age that set the tone for success.

This work is dedicated to my grandmother who always said that I should go for my doctorate. Rest in peace, and as you used to say, “Love ya!”

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# CHAPTER 1

## INTRODUCTION

### 1.1 Overview of the Chapter and Introduction to the Study

The first chapter consists of six sections that provide the background upon which the study was formulated and conducted. Section 1.2 offers the rationale for the study from multiple perspectives. Section 1.3 illuminates the background of the study, while Section 1.4 describes the research questions that were explored. Section 1.5 explains the various instruments utilized in the study, and Section 1.6 offers insight regarding the study's inherent limitations.

Teaching and learning in a school setting is a complex process that has been increasingly criticized (Fuson, 2009), has been studied often, and has evolved continuously. With the recent focus on the education system in the United States of America, in particular, the imposition of school tax caps (currently the State of New York limits school budget increases to the lower of two percent or the rate of inflation (DiNapoli, 2016)) and the mandates for teacher and principal accountability for student performance on standardized tests, it is more important than ever that every educational decision be properly scrutinized. Furthermore, given the cost of educational technologies and other innovations, it is important to consider the least expensive ways to accomplish instructional goals (Clark, 1994; Reigeluth, Beatty, & Myers, 2017).

The challenge, therefore, is to create an optimal learning environment for students to succeed in mastering the new, more rigorous standards of college and career readiness with limited funding. According to the developers of the Common Core State Standards (Common Core State Standards Initiative, 2014, p. 2) that have been adopted by the State of New York, "The standards define the knowledge and skills students should gain throughout their K-12 education in order to graduate high school prepared to succeed in entry-level careers, introductory academic college courses, and workforce training programs." This standardized back-to-basics movement is attempting to provide students throughout the country with the same foundation skills. In English Language Arts, the focus is on communication skills; in mathematics, the instructional shifts include notions, such as multiple representations and

dual intensity that involves mathematical fluency and conceptual understanding (Common Core State Standards Initiative, 2014).

In order to make this new educational vision a reality, several researchers have looked at ways to create versatile learning environments in which learners are active, productive, creative, and collaborative (Chan et al., 2006). According to Project Tomorrow (2010, p. 27), schools must develop "...a new genuine 'student vision' for learning and in particular, the student's experience-based blueprint for the role of incorporating emerging technologies in 21st century education, both in and out of the classroom." According to this study, students' learning environments need to make sense to the students in the classes, and what is readily available in the home should be available for use in school as well. However, such efforts must proceed carefully because modern education and pedagogy cannot be ignored, and techno-centric views, claiming that simple delivery of instructional content implies learning, must be avoided (Chan et al., 2006). This position is aligned to Hattie's (2009, pp. 22-23) findings that teachers play essential roles in student learning and "the act of teaching requires deliberate interventions to ensure that there is a cognitive change in the student."

Many governments have implemented technology programs in their schools, some have been well thought out and others were simply based on the hope that they will improve student achievement (Hew & Brush, 2006). As these initiatives have been introduced, studies have been conducted regarding various aspects of technology use in the classroom, and results have been mixed. In the literature review in chapter 2, a more thorough review of these results will be presented; however, the studies considered in the development of the Lynbrook Public Schools<sup>1</sup> initiative upon which this study is based will be presented here in brief.

This current study expanded upon the prior work with one-to-one and two-to-one laptop implementations, and in particular, it focuses on students' perceptions of their learning environment, their attitudes towards mathematics and achievement in the mathematics classroom. The following works were instrumental to the Lynbrook Public Schools computing initiatives and critical to this study as well. Building upon the premises of the fundamental school paradigm driving the technology integration (Drayton, Falk, Stroud,

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<sup>1</sup> The author is employed as an Assistant Superintendent by the Lynbrook Public Schools.

Hobbs, & Hammerman, 2010) and the necessity of a multiyear model (Suhr, Hernandez, Grimes, & Warschauer, 2010), the notion of a pervasive (Russell, Bebell, & Higgins, 2004), non-rotational two students to one laptop computing model, in which students worked with partners on a daily basis was developed. The essential elements of other studies were also considered (The Abell Foundation, 2008; Bebell & Kay, 2010; McGrail, 2006; Penuel, 2006; Shapley, Sheehan, Maloney, & Caranikas-Walker, 2010). The implementation was rooted in Weston and Bain's (2010) outline for realizing the benefits of cognitive tools.

“The growth of 1:1 programs over the past 20 years has led to a commonly accepted set of ‘best practices’ but little agreement on the proper measures of a ‘successful’ implementation” (Stone, 2016, p. 2). In order to measure such successful implementation, classroom environment instruments can be used as one factor in the evaluation of new educational innovations (Fraser, Tobin, & McRobbie, 2012). In particular, Fraser (1989) emphasizes the importance of students’ perceptions of the learning environment when implementing a new instructional approach. Since the mid-1990s, many learning environment studies have been conducted to investigate the effects of computer use in classrooms in Australia (Maor & Fraser, 1996; Trinidad, Aldridge, & Fraser, 2005) and Singapore (Chang & Fisher, 2003; Teh & Fraser, 1994; Wong et al., 2006).

Other researchers have laid the groundwork for analyzing the teaching and learning of mathematics and also for analyzing the use of laptop technologies in the classroom. This current study was designed to include several variables that provide evidence for success of the program from the students’ perspectives. As Sokolowski, Li, and Willson (2015) noted in their meta-analysis of the effects of using exploratory computerized environments in first through eighth grade mathematics, there have been a limited number of elementary laptop studies in mathematics classrooms where the findings can be generalized. The research reported in this thesis is necessary because additional studies may provide useful insight into students’ perceptions of their mathematical learning needs that could serve as a guide for teachers’ instructional practices in mathematics and other content areas. This study may also provide unique insight into what constitutes effective teaching of mathematics with technology (Attard, 2013). Meta-analyses offer further evidence to support the link between educational environments and student outcomes (Fraser, Walberg, Welch, & Hattie, 1987; Hattie, 2012).

In looking at laptop use in elementary mathematics classrooms, unique aspects of this study included the combined use of elements from the Test of Mathematics-Related Attitudes (TOMRA), which is based upon the Test of Science-Related Attitudes (TOSRA; Fraser, 1981), and the What Is Happening In this Class? Questionnaire (WIHIC) (Aldridge et al., 1999). The study evaluated the learning environment using a pre-posttest comparison of the two students to one laptop computing model (2:1 computing) compared to the traditional one student to one laptop computing model (1:1 computing) and the students' attitudes to mathematics and their achievement in mathematics. The study also contains a triangulation element with a qualitative component to assist in the interpretation of the quantitative results. The combination of the two techniques of quantitative and qualitative data collection has previously been successfully used in learning environments research (Aldridge et al., 1999; Earle & Fraser, 2016; Fraser & Tobin, 1991; Tobin & Fraser, 1998).

The target population for the study was the 453 fourth and fifth grade students, attending three elementary schools that are part of the Lynbrook School District located on Long Island in the state of New York. The district is on the smaller side with an enrollment at that time of approximately 2,850 students in grades kindergarten through twelve. This study focuses on a small but critical microcosm of students' mathematical school years, namely the upper elementary grades, fourth and fifth. Up until this experience, all of these students were taught in classrooms with little access to computing technology. Each of their prior classrooms was outfitted with approximately two computers, allowing for limited support during mathematics class. Since these students were introduced to laptops, as permanent fixtures in their classrooms, for the first time in their school experiences, the use of laptops offered unique perspectives on this new learning environment.

During the pre-assessments, students completed both the TOMRA and WIHIC; toward the end of the school year, they responded to the same questions again after experiencing a year with laptops. This allowed the students to serve as their own controls in this quasi-experiment design with pre- and posttest data (Campbell & Stanley, 1963; Penuel, 2006). In addition, students were assigned to either 1:1 or 2:1 computing environments, allowing for a comparison between the two interventions. In each of the classrooms, the effects of the learning environment on students' attitudes and achievement were measured. These results were then combined with direct observations in the classrooms to provide a fuller picture of exactly what was going on in the 1:1 and 2:1 learning environments.

## 1.2 Rationale for the Study

Since The Third International Math and Science Study (TIMSS), mathematics education has had increased attention in the United States (Schmidt, n.d.). One of the reasons is that the United States was the only country included in TIMSS that went from above average in mathematics in fourth grade to below average in eighth grade (United States Department of Education, 1998). This result was deemed unacceptable, so much so that it birthed new legislation.

The No Child Left Behind Act of 2001 required that states in the USA make efforts to raise academic achievement levels for all students (Simpson, Lacava, & Graner, 2004). This lofty task was to be accomplished through the implementation of a rigorous testing program in all mathematics and English Language Arts classes in grades three through eight. Professional development, curriculum, and instructional changes were also mandated without further instruction; the details of the professional development, curriculum, and instructional changes were left to the states and local educational agencies. The success of the NCLB act remains a continual source of debate and the validity of the tests instituted were and continue to be subject to harsh criticism (Winerip, 2011).

Despite the issues, the NCLB act solidified that there was a need to find out and address what went wrong in the students' learning environment between the fourth and eighth grade examinations for U.S. students which became a focus for the country and a challenge for all those in the field of education (Protheroe, Shellard, & Turner, 2003). Overseas practices were examined and the conclusions were made that American mathematics curricula covered too much information not allowing for necessary depth. For example, studies conducted in Singapore confirmed deeper coverage of a relatively small number of topics (Institute of Education Sciences, 2009). This concept became generally accepted in the U.S. and it was memorialized by the Every Child Achieves Act of 2015 (Office of the Press Secretary, 2015, p. 1) that reauthorized and amended the tenets of the original Elementary and Secondary Education Act of 1965 (ESEA) and, in essence, The No Child Left Behind Act of 2001. The conclusions of both acts have been clear. Students must be given time to work independently to construct their own understandings, solve real world problems, and effectively present their findings. The Every Child Achieves Act of 2015 challenges schools to create classrooms where rigorous teaching and learning can take place.

As it is defined, 1:1 computing refers to the level at which access to technology is available to all students and teachers; it does not imply anything about actual educational practices (Bebell & O'Dwyer, 2010). In order to move toward more rigorous teaching and learning, “the derivation and delivery of a method to support learning is always necessary” (Clark, 1994, p. 26). Since mastering the use of the technology is not the goal of the implementation, 1:1 computing initiatives must be examined as part of greater educational reform models and programs, in order to examine the actual goal of improving the learning process and the classroom environment in which teaching and learning occur (Bebell & O'Dwyer, 2010; Shapley et al., 2010; Weston & Bain, 2010).

Laptop use can facilitate a more constructivist approach to teaching that could become a ‘theoretical basis’ for technology-enhanced learning environments (Gulek & Demirtas, 2005; Kang, Choi, & Chang, 2007). Advances in technology allow teachers “to adopt a social constructivist approach to teaching and learning. In these learning environments, discussion, social interaction, collaboration, peer feedback, and group projects can be adopted as teaching and learning strategies” (Keppell, Au, Ma, & Chan, 2006, p. 456). It is important to note that focus of constructivism is on acquiring knowledge and building understanding; it is not a theory of teaching (Hattie, 2009). However the teacher does facilitate the classroom activities and plays a primary role in influencing student learning (Clark, 1983; Tay, Lim, & Lim, 2013). The role of the teacher in the learning process cannot be underestimated because 1:1 computing does not cause an automatic, easy shift in classroom dynamics (Garthwait & Weller, 2005). In fact, teachers are crucial in technology-enhanced learning environments, and many studies have shown that teachers’ beliefs and practices are critical to successful technological integration (Chere-Masopha & Bennett, 2007; Garthwait & Weller, 2005; Hayes, 2007; Penuel, 2006; Raes, Schellens, Wever, & Vanderhoven, 2012; Tay, Lim, & Lim, 2013; Towndrow & Vaish, 2009). When teachers adopt constructivist approaches rather than traditional approaches to teaching mathematics in addition to incorporating technology, larger effect sizes on mathematics achievement have been found (Li & Ma, 2010).

With the lofty expectations for laptops, and emerging technologies in general, come great responsibilities. It is imperative that attitudinal and achievement information be collected at the elementary level to measure the impact of such initiatives. Shapley et al. (2010) presented positive results on the Texas middle school mathematics assessments (TAKS), yet

the results were not always statistically significant, even though the ultimate goal for using technology in the classroom was to increase student achievement as measured by the state assessments. More positive findings were reported by Pilli and Aksu (2013) who conducted a study of 29 fourth graders receiving computer-assisted instruction and 26 fourth graders in a traditional class setting in North Cyprus which included both positive effects on students' attitudes toward mathematics and their immediate achievement. Other researchers have experienced mixed results; significant positive effects of laptop use on student achievement (Efaw, Hampton, Martinez, & Smith, 2004; Gulek & Demirtas, 2005; Siegle & Foster, 2001) and negligible or no statistically significant effects of laptop use on achievement (Dunleavy & Heinecke, 2007; Gardner, Morrison, Jarman, Reilly, & McNally, 1994). Although Bebell and Kay (2010, p. 21, 44) found "strong evidence that student engagement increased dramatically in response to the enhanced educational access and opportunities afforded by 1:1 computing through the pilot program," they also concluded that the analysis of the results on the Massachusetts state assessments "revealed some positive, yet far from conclusive, results on the impacts of the 1:1 pilot program on student learning."

This current research study was designed to examine the learning environment, mathematics attitudes and achievement of fourth and fifth grade students. First, the results of the research study will directly profit the participating schools by providing evidence to either support or refute the benefits of their 2:1 computing program in the mathematics classrooms. The comparing and contrasting of this atypical 2:1 model versus the more traditional 1:1 computing program can help the Lynbrook School District leadership decide whether or not one model makes more sense than the other in this locality, or determine if neither model was producing the anticipated results.

Second, for those in the field of education, the results of the study may shed light on the potential impact of different types of 2:1 computing in the classroom. Using the aforementioned research as a guide, the 2:1 computing model was designed to support students learning in a constructivist environment. The connections or lack thereof between and among learning environments, student attitudes toward mathematics, and achievement in this unique model may spark interest in replication of the model and further study.

### 1.3 Background of the Study

In 1999 the United States Chamber of Commerce Foundation (n.d.) popularized two important educational terms, namely 21<sup>st</sup> Century Skills and Science Technology Engineering and Mathematics (STEM). The first term, 21<sup>st</sup> Century Skills refer to all the skills necessary to be successful both in school and in the workforce during this century. These skills include but are not limited to communication skills, problem solving skills, and interpersonal and self-direction skills. Marzano and Heflebower (2012) divide these skills into two types, ‘cognitive’ and ‘conative.’ They use the term cognitive to refer to the traditional academic skills, necessary to do well in school; conative describes all of the required interpersonal skills. Students must now master both content and skills (Partnership for 21<sup>st</sup> Century Skills, 2009). This dual focus has begun to change subsequent learning environments in the United States. Instead of focusing on memorization of facts and understanding of scholarly information, classrooms have been redesigned to foster critical thinking, problem solving, communicating, collaborating, technological literacy, adaptability, creativity, global competency, and financial literacy. Not only have these standards infiltrated local and state curricula via mandates, most recently through the Common Core State Standards (Common Core State Standards Initiative, 2014), but also they are included in Warschauer’s (2006) primary reasons that states and individual school districts start 1:1 computer programs. It has been made clear that teaching cannot focus entirely on transmitting factual knowledge; other 21<sup>st</sup> century skills also must be explicitly taught (Saavedra & Opfer, 2012). The connection here is the teacher’s responsibility to design lessons and foster a learning environment where there is a free discourse of ideas centered on specific problems.

Constructivist teaching methods have been employed in the Lynbrook School District for several years. Teachers are continuously attempting to modify or replace their lessons with a more student focus. The negotiated tool used to evaluate Lynbrook teachers’ classroom performance and to collect qualitative data for this study (see Appendix A) is based heavily upon the work of Danielson who rewards teachers for student performance (Danielson, 2007). The rubric was the product of an observation committee of district teachers and administrators and serves to set the district expectations. Since Danielson’s descriptions of the top ratings in each category describe student-driven behaviors, a constructivist approach is typical in the Lynbrook School District and is required for teachers to receive a distinguished rating. The constructivist approach to teaching and learning has been further

developed in Section 2.3 as it relates to student learning outcomes and the learning environment. Although empirical data cannot be included in this study to demonstrate the volume of constructivist technology-driven lessons and this limitation will be discussed in Chapter 1.6, the principals conducted bi-weekly lesson plan checks, and at a minimum weekly, informal observations, grade level and data meetings to monitor teaching and learning in every classroom.

Members of the fourth and fifth grade teaching staff showed interest in the technology initiatives happening in nearby districts, and after many conversations with different constituencies and learning about some educational research, the Lynbrook School District introduced its laptop programs in grades four and five in order to provide students with a technology-enhanced learning environment via laptop computers. These grades were selected for the pilot study because the District believed that both these students and teachers would be best prepared for such an undertaking. Subsequently, teachers worked together with the District's instructional technology staff developer on the vision for the program and corresponding professional development. Teacher involvement in the early stages and throughout the professional development was critical (Ertmer & Ottenbreit-Leftwich, 2010; Weston & Bain, 2010) so that the focus was on integrating the technology into the teachers' constructivist pedagogy. Weston and Bain (2010) set the goal that teaching, learning, and technology should be 'integrated' and 'inseparable,' and Ertmer & Ottenbreit-Leftwich (2010, p. 256) advised to "shift our mindsets away from the notion that technology provides a supplemental teaching tool and assume, as with other professions, that technology is essential to successful performance outcomes (i.e., student learning)." During these planning meetings about introducing laptops into the classroom, teachers stated that both the 1:1 computing and 2:1 computing models could meet their instructional and their students' learning needs and were curious as to how the learning environments would differ.

Since it was known that "the lack of a start-up year for planning was a major barrier to effective implementation" (Shapley et al., 2010, p. 45), the process of preparing the fourth and fifth grade teachers started in the spring semester before the laptops were introduced. Again, to avoid another potential obstacle - technical failure - the students received support throughout the school year in their classrooms from their teachers, the school's library media specialist, and the District's instructional technology staff developer (Stone, 2016). This support was essential to the success of the program. Also, important was the continuous

cycle of feedback and refinement; teachers, administrators, and the technology staff met on a monthly basis throughout the year to discuss the implementation and receive ongoing professional development. In order to make the implementation and school, dynamic and successful, constant feedback must be solicited (Weston & Bain, 2010). Islam and Gronlund (2016, p. 211) warn that “without a continuous monitoring and evaluation, including finding the learning impact based on a systematic framework, any project implementation will lead to uncertainty, difficulty to find and define the scope of improvement, and consequently a considerable risk for failure.”

Consequently, this current study also constitutes a form of feedback and will offer the Lynbrook School District information regarding the learning environment and attitudinal changes in its mathematics classes and possible implications for its students’ achievement levels. It will also deliver a basis for comparison of the differences between students learning in the 1:1 and 2:1 computing learning environments.

#### **1.4 Research Questions**

The main purpose of the research was to compare the learning environments, attitudes towards mathematics, and achievement in mathematics of fourth and fifth grade students who were learning mathematics in 1:1 (one laptop for every student) and 2:1 (one laptop for every two students) computing learning environments and determine whether or not, compared to 1:1 computing, 2:1 computing initiatives foster a positive learning environment, improve student attitudes towards mathematics, and increase student achievement in mathematics.

Specific research questions were:

1. Are there differences in students’ perceptions of their learning environments when studying in 1:1 or 2:1 computing environments?
2. Are there differences in students’ mathematics attitudes when studying in 1:1 or 2:1 computing environments?
3. Are there statistically significant correlations between the learning environment scales, students’ mathematics attitudes, and mathematics achievement when studying in 1:1 or 2:1 computing environments?

## **1.5 Instruments Used in the Study**

The study was multifaceted and utilized both quantitative and qualitative measures in order to describe the learning environments. The students offered several sources of quantitative data by completing learning environment and attitudinal surveys, and taking two New York State Mathematics Assessments (NYSE).

Due to the relatively small sample size and inability to validate a brand new instrument, the surveys selected are instruments with proven validity and reliability with similar grade levels as in this study. The foundation of one survey is the TOMRA (Fraser, 1981) and the second is the WIHIC (Aldridge et al., 1999). Slight modifications (see Appendix B) were made to the TOMRA to tailor it to the needs of the Lynbrook School District. The WIHIC was used in its entirety (see Appendix C). Permission was sought from and granted by Fraser to use both surveys (see Appendix D).

The final instruments used were the NYSE. For the fourth grade participants, their 2010 NYSE Grade 3 Mathematics Assessment scores were compared to their 2011 NYSE Grade 4 Mathematics Assessment scores. For the fifth grade participants, their 2010 NYSE Grade 4 Mathematics Assessment scores were compared to their 2011 NYSE Grade 5 Mathematics Assessment scores. All four examinations were created by CTB/McGraw-Hill LLC (2010a, p. 5; 2011, p. 5) and consisted of multiple choice and short answer questions; “as a result of the alignment to both process and content strands, the tests assess students’ conceptual understanding, procedural fluency, and problem-solving abilities, rather than solely assessing their knowledge of isolated skills and facts.” The scoring rubric and conversion scales for the NYSE were made in conjunction with the New York State Department of Education.

## **1.6 Limitations**

Since the researcher was supervising in the District being studied, every precaution was taken to protect both the students and teachers. The agreement with the teachers, students, parents, and other administrators was that the research would be conducted in as minimally invasive way as possible. This meant that the time commitment on the part of the students and teachers was limited to completing the pre- and post- TOMRA and WIHIC surveys, without the researcher being present thereby ensuring the teachers’ anonymity. In addition,

observations and natural conversations were to occur during normal instructional periods only and be conducted using the current Lynbrook Teacher Observation Form (Danielson, 2007) by district administrators and be reported in both the learning environments, 1:1 and 2:1 computing, and compiled in note form without reference to specific classes or teachers. No additional teacher and/or classroom data was to be collected. Finally, no new assessments were to be introduced, so mathematical achievement data would be collected, via the only required common assessments, which are the state assessments. Unfortunately, after the study was conducted, the NYSE received significant criticism and continues to receive criticism to the point where the validity of the assessments must be questioned (Brody, 2016).

The aforementioned contributed to the following limitations: teacher differences, implementation fidelity, and data collector and bias threats (Fraenkel & Wallen, 2006). Additionally, the Hawthorne effect was naturally present due to the novelty of the treatments (Fraenkel & Wallen, 2006, p. 177). These limitations and how they were addressed is discussed in Chapter 5.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Overview of the Chapter

This chapter puts forth literature related to this study. Section 2.2 sets the perspective for the rest of the chapter. Next, Section 2.3 describes typical features of mathematics learning environments and also considers constructivist, problem solving, and small group approaches. In Section 2.4 technology use in elementary education is discussed including: laptop initiatives, the role of the teacher, and the enVisionMATH program (Pearson Education, 2011). Section 2.5 follows with a discussion of students' attitudes toward elementary mathematics and the instruments used in this study to measure them. Finally, Section 2.6 explains classroom mathematics assessments, the history of mathematics assessments in the State of New York, and the NYSE included in this study. Section 2.7 summarizes the chapter.

#### 2.2 Introduction

Using Fraser et al. (2012) as a guide, learning environment assessments were used alongside assessment data to provide a fuller description of the learning environment, that included subtle constructs such as student cohesiveness, teacher support, involvement, and investigation designed to help measure the effectiveness of the classroom innovations. In order to understand the impetus behind this study, learning environment research is presented, and three common approaches employed in mathematics classes, namely constructivism, problem solving, and small group instruction are explored.

The incorporation of technology into mathematics learning environments follows, with a particular focus on the technologies in this study. In order to create the positive effects of introducing computers into the learning environment, the introduction of technology is not enough because computers only represent a part of the necessary educational change (McGrail, 2006). Therefore, the role of the teacher and the EnVision Math program used in Lynbrook Public Schools to support the teachers' instruction is also described.

Student attitudes towards elementary mathematics are discussed, and the instruments used to measure these attitudes are analyzed. The collection of student feedback is important because the students may have different perceptions of the class than the teacher so that making changes to the learning environments to be more similar to those preferred by the students may have positive impacts on student outcomes (Fraser et al., 2012). Finally, ways to measure achievement in elementary mathematics classes are offered, and the state examinations used in this study are explained in more detail.

### **2.3 Mathematics Learning Environments**

To analyze instructional problems and to develop the foundations for instructional theories, necessary conditions must be established (Clark, 1983). In order to understand students' ability to comprehend mathematics in the elementary classroom, it is imperative to look at the learning environment and good pedagogy to 'guarantee' improvements (Islam & Gronlund, 2016; Moos, 1980). One way to examine the learning environment and teaching of mathematics is from the students' perspective.

The use of student voice and comparison of their perceptions of mathematics teaching and learning with existing research literature and frameworks for effective teaching of mathematics provided rich insight into what constitutes effective teaching of mathematics. (Attard, 2013, p. 585)

This emphasis on the students' perspectives is aligned to learners being the 'center' and an 'integral' part of the learning environment (Hannafin & Land, 1997).

In order to focus on the needs of the students, the following factors were considered important: 'being creative (constructing, discovering),' problem solving, and peer learning in small groups (Kang et al., 2007). These concepts provide the basis for the following subsections.

#### **2.3.1 Constructivism**

Constructivism in the classroom has its roots in the works of Piaget and Vygotsky and has become one of the most current psychologies of learning, focusing on cognitive development and deep understanding through the use of human self-organizing tendencies (Fosnot & Perry, 2005). As applied in mathematics classrooms, constructivism is a non-linear approach

to teaching elementary mathematics based upon building constructions of understanding (Hattie, 2009). “Understanding, it is argued, is neither inherently hierarchical nor the product of incremental teaching methods, but a natural consequence of curiosity, experience, reflection, insight, and personal construction” (Hannafin & Land, 1997, p. 181). Students actively derive meaning through processes such as making connections, finding patterns, identifying rules, and abstracting principles (Garner, 2007).

Students develop their own mathematical senses through exploring mathematical concepts and learning from their mistakes. As students begin to correct their own errors, reconcile discrepancies, and dispel misconceptions, they are in control of refining their own understandings (Hannafin & Land, 1997; Hattie, 2009). In order to foster learning strategies necessary for students to construct understanding, teachers need to provide opportunities and alternatives to develop their own questions, generate and test hypotheses, and communicate their ideas to the classroom community (Fosnot & Perry, 2005; Hattie, 2009).

When employing a constructivist approach, teachers’ roles change as they provide individualized attention taking into account students’ background knowledge and beliefs about the discipline, facilitate group discussions exploring content in order to lead students toward shared understanding, infuse formal knowledge about the discipline directly and through a variety of print and digital sources, engage students in purposeful tasks aimed at challenging or enhancing current student beliefs, and develop student awareness of their personal understandings and the learning process (Richardson, 2003). As noted by Fosnot and Perry (2005), “learning is not the result of development; learning is development” (p. 33).

### **2.3.2 Problem Solving**

When teachers develop lessons focusing on problem solving they challenge and encourage students to dissect problems and develop possible solutions, either individually or in small groups (Hattie, 2009). Problem solving is described using four principles: understanding the problem, devising a plan, carrying out the plan, and looking back (Polya, 2014).

Furthermore, students can use and develop a variety of strategies including: guess and check, determining patterns, solving simpler problems, considering special cases, working backwards, using direct reasoning, using a formula, and solving an equation.

Since there is no ‘general’ problem solving approach that works in all contexts, Kim and Hannafin (2011, p. 405) “define problem solving as situated, deliberate, learner-directed, activity-oriented efforts to seek divergent solutions to authentic problems through multiple interactions amongst problem solver, tools, and other resources.” For students to be successful, these interactions need to be positive. Unfortunately, many students use ‘ineffective strategies’ and do not seek help from other resources in the classroom, including the teacher and other students (Raes et al., 2012).

### **2.3.3 Small Group Instruction**

In order to support students in their constructivist and problem solving efforts, a class of students is often divided into smaller groups. Indeed, many student-centered classrooms are designed to allow students to construct shared understandings (Hannafin & Land, 1997). In such learning environments, students are encouraged “to take responsibility for their own learning by communicating with other students, providing feedback to other students and receiving feedback from other students within the group setting” (Keppell et al., 2006, p. 462). Eventually, as students become more accustomed to working in small groups, they begin to assume more responsibility for teaching themselves. The impact of small group instruction was found to be most effective when groups had prior experience, specific cooperative learning strategies were encouraged, and the group sizes were small (Hattie, 2009).

Other benefits of small groups have been propounded as well. In their meta-analytic review of peer-assisted learning interventions with elementary school students, Rohrbeck, Ginsburg-Block, Fantuzzo, and Miller (2003) identified positive influences of socialization on: achievement, task orientation, persistence, and motivation to achieve. When laptops are introduced in such a learning environment, students are offered other ways to connect with peers based upon their common goals and interests (Warschauer & Tate, 2015). The effects of technology use in elementary education forms the basis for this current research study and are discussed in depth in Section 2.4.

## **2.4 Technology in Elementary Education**

Similar to other fields, educators must allow form and function of usage to drive computer access, not vice versa (Weston & Bain, 2010). As described in the previous section, approaches to teaching elementary mathematics, such as constructivism, problem solving, and small group instruction can be considered the ‘theoretical grounding’ for technology implementation (Kang et al., 2007). The choice of technologies is important because it can lead to certain conceptualizations and establish the types of learning activities and how the students are diagnosed and assessed (Drayton et al., 2010).

In the Crossriver School District, located in New York, Lowther, Ross, and Morrison (2003) used surveys, interviews, focus groups, and observations to study technology use of fifth through seventh grade students. The researchers found classes that were assigned with technology employed more student-centered teaching strategies, including project-based learning, independent inquiry, and cooperative learning, compared to the control classes without technology (Lowther et al., 2003).

Technology-enhanced, student-centered learning environments can be designed in such a way as to promote activities, such as sampling, discovering, manipulating, and investigating (Hannafin & Land, 1997). As teachers facilitate and monitor students in their construction of knowledge in technology-supported learning environments, students are often asked to justify their new understandings by providing evidence to support their tentative theories and solutions (Kim & Hannafin, 2011). This process requires continuous feedback and the importance of the role of the teacher is emphasized as is discussed in Section 2.4.2.

In technology-enhanced, student-centered learning environments, students take active roles in the classroom and use the resources and tools offered by the integrated technologies to enhance their word problem-solving skills (Sokolowski et al., 2015). Furthermore, these learning environments can “organize interrelated learning themes into meaningful contexts, often in the form of a problem to be solved or an orienting goal, that bind functionally their features and activities” (Hannafin & Land, 1997, p. 168). In student-centered environments designed this way, technology becomes an integral part of the problem solving process.

Small group learning in technology-enhanced learning environments has been shown to have more positive effects than individual learning (Li & Ma, 2010). The small groups allowed for collaborative learning activities that were “facilitated by a shared learning platform which incorporates individual learning activities into a reciprocal learning activity” (Wu & Liu, 2015, p. 456). Through this collaboration, it is possible that ‘distributed knowledge’ emerges and a learning community is formed (Salomon, 1998; Wu & Liu, 2015).

Despite the fact that many technology initiatives have re-hosted, not re-defined teaching and learning, the potential for optimizing advancing technologies and supporting student-centered learning remains (Garza, 2015; Hannafin & Land, 1997). As technologies continue to progress, ‘disciplined methods’ must be employed in order to integrate the available digital resources and tools to support student-centered learning (Hannafin, Hill, Land, & Lee, 2013). In order to be successful, 1:1 laptop programs cannot exist in isolation and must be grounded in reformed teaching agendas (Bebell & O’Dwyer, 2010; Weston & Bain, 2010; Zuber & Anderson, 2012).

#### **2.4.1 Laptop Initiatives**

Of particular interest to this current study are laptop implementations. The Abell Foundation (2008) detailed findings regarding major 1:1 laptop initiatives throughout the United States, primarily at the sixth and seventh grade levels. The findings regarding student achievement were inconclusive, student engagement ‘appeared’ to increase as learning was more student-centered, and a phased-in implementation was recommended. Drayton et al. (2010, p. 13) focused on schools beyond the first cycle of implementation and examined science classrooms with five or more years of implementation of 1:1 computing through “teacher reports, student questionnaires, school or district documentation, interviews with principals and other school personnel, and multiple observations of each classroom.” The lessons learned included: teacher variation exists and ‘structured persistence’ is necessary, fundamental paradigms (teacher versus student centered) impact the 1:1 approach, teachers’ educational beliefs and school culture shape technology integration, and teachers need meaningful professional development structured to allow discussions regarding content, pedagogy, and technology. Similar findings to Drayton et al. were found in a qualitative research study of the perspectives of secondary English teachers (McGrail, 2006) and a quantitative study evaluating 1:1 computing initiative in 21 Texas middle schools across

three implementation years, using surveys and state test data (Shapley et al., 2010). In addition, the researchers in the latter study found that only four out of the 21 schools studied reached what they deemed to be substantial levels of technology integration; a lack of a planning year was a barrier to success in the other 17 schools.

Other studies offered different insights. Suhr et al. (2010) used mixed methods to study 54 fourth grade students in California for a two year period in English Language Arts classes. The researchers found that the achievement levels of students in the laptop classes increased more than their comparison peers in a traditional program in the same school district only after the two year period, although this result was not statistically significant. In a similar study, Bebell and Kay (2010) studied students in five Massachusetts middle schools over a three year period using a pre-posttest design, primarily in mathematics and English Language Arts. Most results were not conclusive; however, the role of the teacher in the success of the 1:1 initiative was critical. A research synthesis of 30 articles regarding 1:1 initiatives concluded that gains in student achievement were not conclusive, teacher professional development and willingness to participate were essential components of successful programs, and also when students had more practice with technology (Penuel, 2006). In addition, the findings emphasized that “many of the initiatives focused on transforming teaching specifically to make instruction more ‘student-centered,’ that is, more differentiated, problem- or project-based, and demanding of higher-order thinking skills” (Penuel, 2006, p.335). As noted earlier, the push toward student-centered instruction has been bolstered by the popularity of Charlotte Danielson’s Framework for Teaching (Danielson, 2007), currently being used for teacher evaluations in more than half of districts in the State of New York, according to the 2016-2017 approved professional performance review plans (New York State Education Department, 2017).

Although the aforementioned research contributed to the formation of this study and the computing initiatives in the Lynbrook Public Schools in which the study was conducted, Weston and Bain’s (2010) work played a pivotal role offering a theoretical framework for student educational improvement and a vision for ‘self-organizing schools,’ where laptops are an integral part of the learning environment. According to Weston and Bain (2010), for laptop or other technological devices to impact teaching and learning, schools should: clearly define a list of ‘simple rules’ for teaching and learning as a community, use the ‘simple rules’ to inform how the school functions on a daily basis, actively involve all members of the

school community in maintaining and redefining the school, solicit feedback from all constituents in real time to inform school initiatives, develop a ‘conceptual framework’ to define relations within the school community to promote learning, and cultivate a community expectation that technology use is pervasive. These principles served as both guidance and aspirational goals for the Lynbrook Public Schools. Another major contributor to the current study was the comparative effects of different ratios, 1:1, 2:1, and 4:1 computer arrangements on learning in mathematics, science, language arts, and social studies classes of 209 upper elementary students in Massachusetts through observations and surveys without a pre-posttest design (Russell et al., 2004). The conclusion was that the low access in the 2:1 and 4:1 classes, where the laptops were only in the classrooms every two or four weeks, did not allow for the same teaching and learning benefits as the 1:1 classes that had more technology use and less large group instruction. Furthermore, it was advised that “rather than undertaking research that focused on technology use and student achievement in relatively low access and low use settings, it seems prudent to focus this research on high access settings where the technology is pervasive” (Russell et al., 2004, p. 328).

#### **2.4.2 Role of the Teacher**

As stated earlier, teachers play vital roles in the success of technology or laptop initiatives. “Even with an elaborate technological infrastructure, teaching and learning would not be possible without committed and skillful teachers who are on the ground implementing the day-to-day lessons in their respective classrooms” (Tay, Lim, & Lim, 2013, p. 35). In other words, individual teachers determine how students are instructed in their respective classrooms. The success or failure of 1:1 computing rests with classroom teachers; they are the ones who decide when and how students have access to technology on a daily basis and are also the ones who must spend hours adapting their materials and practices to make relevant use of 1:1 computing (Bebell & Kay, 2010; Drayton et al., 2010).

Since variation in teachers’ instructional practices and content selections will affect how 1:1 computing is implemented in individual classrooms, it is imperative that teachers are given co-planning time to produce a more uniform instructional implementation (Clark, 1983). As an example, in a fourth grade 1:1 computing implementation in Singapore, this was accomplished through grade level meetings during which lessons were developed collaboratively and shared (Tay, Lim, & Lim, 2013). In order to develop meaningful,

technology-rich lessons, teachers must be well prepared, “with a clear goal in mind and a supporting infrastructure that makes effective use possible” (Peck & Sprenger, 2008, p. 936). Professional development must be designed in such a way as to expand teachers’ knowledge and promote their self-efficacy, while accounting for their pedagogical beliefs and classroom culture and attending to their curriculum and instructional needs (Ertmer & Ottenbreit-Leftwich, 2010; Garza, 2015). Technology must be part of normal instruction in the classroom, not an add-on, and peer and other staff development demonstrations could be powerful tools to illustrate how technology can become fully integrated and used to teach both existing and expanded content (Ertmer, Paul, Molly, Eva, & Denise, 1999).

The strongest predictors of effective technology use are positive teacher beliefs regarding both student-centered instruction and technology as an instructional tool (Garza, 2015). Again, “for many teachers, possessing the relevant knowledge, confidence, and beliefs is enough to empower them to integrate technology into their classrooms in meaningful ways” (Ertmer & Ottenbreit-Leftwich, 2010, p. 264).

### **2.4.3 enVisionMATH**

To support teaching and instruction in elementary mathematics, the Lynbrook Public Schools formed a committee of teachers, parents, and administrators to select a mathematics program aligned to the District’s vision and pedagogy. The teachers in particular expressed that this program was best aligned to their curricular goals and voiced how they appreciated that it offered technological and data mining features, foreseeing benefits in the future. Since the literature has reported a lower level of use of laptops in mathematics classrooms than in other subject areas (Zuber & Anderson, 2012), providing a starting point for teachers to more easily implement technology in their mathematics classes made sense to the teachers and the rest of the District committee.

Subsequently, the enVisionMATH program (Pearson Education, 2011) was considered by its authors as offering a strong mathematics curriculum that is differentiated in such a way as to allow for teacher creativity and meet students’ various learning styles and needs in grades kindergarten through six. During the 2007-2008 and 2008-2009 school years, under the supervision of an independent research firm PRES Associates, the research and validity of

the program to teach vital mathematical concepts was established in conjunction with the What Works Clearinghouse Study Review Standards (Pearson Education, 2011).

The structure of the program was based upon Wiggins and McTighe's (1998) *Understanding by Design* model for lesson planning. This meant that the process for lesson and unit development began by identifying the expected outcomes. All instruction and activities were then centered about the essential questions and understandings surrounding those outcomes. The mathematical topics covered in the fourth grade curriculum included: numeration, meanings of the four basic operations, patterns and expressions, geometry, operations with fractions and decimals, measurement, equations, and probability and statistics; the mathematical topics covered in the fifth grade curriculum included: numeration, four basic operations with whole numbers and decimals, variables and expressions, geometry, fractions, decimals, and mixed numbers, measurement, solving, writing, and graphing equations and inequalities, ratio and percent, and probability and statistics (Pearson Education, 2011).

## **2.5 Students' Learning Environments, Attitudes toward Elementary Mathematics**

In order to determine the effectiveness of educational innovations, such as technology initiatives, student perceptions of the learning environment are recommended as a source of process criteria (Teh & Fraser, 1994). Students are able to provide unique perspectives because they participate in the learning environment every day and have experienced different learning environments throughout their school time; furthermore, as participant learners, the students may capture information that an observer may otherwise overlook (Fraser et al., 2012). In a study of 1,512 primary mathematics students in Singapore, Goh and Fraser (1998) were able to use student attitudinal surveys to distinguish nuances of the learning environment. The researchers found that cohesive classes with predictable and helpful teachers realized better achievement and student attitudes, while interpersonal teacher behaviors and classroom climate only affected student attitudes, not student achievement.

In a study of 29 fourth grade students receiving computer-assisted instruction and 26 students in a traditional class setting, statistically significant differences in student attitudes were found in favor of those who were in the experimental group, as measured by both the Mathematics Attitude Scale and Computer Assisted Learning Attitude Scale (Pilli & Aksu, 2013). The use of two attitudinal scales to measure the elementary mathematics learning

environment was similar to the current study; however, the instruments used varied in that both were significantly shorter, 20 and 10 items respectively, and measured single factors.

### **2.5.1 What Is Happening In this Class?**

The WIHIC is currently the most widely-used learning environment questionnaire throughout the world (Aldridge & Fraser, 2000; Chionh & Fraser, 2009; Earle & Fraser, 2016). Not only does it bring “parsimony to the field of learning environments by combining modified versions of the most salient scales from a wide range of existing questionnaires with additional scales that accommodate contemporary educational concerns (e.g. equity and constructivism)” (Fraser, 1998, p. 13), but also its validity and reliability have been established throughout the world (Aldridge et al., 1999; Chionh & Fraser, 2009; Dorman, 2003; Fraser et al., 2012) and the United States (Allen & Fraser, 2007; Martin-Dunlop & Fraser, 2008; Ogbuehi & Fraser, 2007), including New York (Wolf & Fraser, 2008). Due to the small sample size of the current study, these established validity and reliability issues were essential features for selecting this instrument for the study.

Compared to other learning environment surveys, the seven scales of the WIHIC, namely: Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity, offer comprehensive insight into the multiple facets of student learning environments and in conjunction with the scales of the instrument to measure students’ attitudes towards mathematics (TOMRA), enumerated in Section 2.5.2, comprised the measures of students’ perceptions and attitudes in this study. It is important to note that since the items of the WIHIC take a personal form, they measure interactions with individual students, as opposed to a class form that measures individual student’s perceptions of the class as a whole (Fraser et al., 2012). In addition, Fraser et al. (2012) believe that student’s perceptions of his/her individual roles, as opposed to their projections about the class as a whole that the researchers feel are typically more favorable, offer a more accurate depiction of the learning environment.

### **2.5.2 Test of Mathematics-Related Attitudes**

In order to obtain a more accurate description of the elementary mathematics learning environment, the TOMRA was used in conjunction with the WIHIC to collect students’

attitudes specific to the field of mathematics (Aldridge et al., 2004; Ogbuehi & Fraser, 2007; Spinner & Fraser, 2005). As discussed in Section 1.1, the modifications to the Test of Science-Related Attitudes (TOSRA) to create the TOMRA were primarily replacements of the word ‘science’ with the word ‘mathematics;’ “for example, “Science lessons are fun” was changed to “Mathematics lessons are fun” (Spinner & Fraser, 2005, p. 271). The TOMRA and TOSRA have both been proven reliable and valid in studies throughout the world (Fraser, 1981; Khalili, 1987).

In this study, items from the following three scales of the TOMRA were measured: Attitudes Towards Mathematics Inquiry, Adoption of Mathematics Attitudes, and Enjoyment of Mathematics Lessons. As noted in Section 2.5.1, combined with the scales of the WIHIC, these instruments provide data on the students’ attitudes to mathematics and perceptions of the learning environment in this study. Similar to the WIHIC, the items of the TOMRA take a personal form. Fraser (1981, p. 6) considered that relative interpretations using the TOMRA to be more meaningful than absolute ones and that measurements “at two separate times can provide valuable information about changes occurring in student attitudes,” especially when comparing two groups of students following ‘alternative teaching methods.’

### **2.5.3 Danielson Framework for Teaching**

Even though the Danielson Framework for Teaching was not written for evaluative purposes, it is on the short list of New York State approved rubrics for teacher evaluation and was selected as the standard by which to measure teachers in more than half of the districts in the state. In addition to New York, several other states have approved or adopted the Danielson Framework for Teaching, including: Illinois, Delaware, Idaho, South Dakota, Florida, New Jersey, Arkansas, and Washington (PR Newswire Association LLC, 2011). Sartain, Stoelinga, and Brown (2011) state that Danielson Framework for Teaching is the ‘most well-known example’ of a tool used to evaluate whether or not effective teaching is taking place. This rubric was used in this study to collect observational data, since it is native to the Lynbrook Union Free School District and familiar to the teaching staff being observed.

## **2.6 Student Achievement**

Student achievement was measured quantitatively in this study utilizing the New York State Examination (NYSE); however, ‘achievement’ can be defined as performance scores on either standardized or teacher-made examinations (Li & Ma, 2010). Regardless of the definition, there have been a limited number of studies and a lack of conclusive evidence to show the effects of laptop programs on student achievement (The Abell Foundation, 2008; Penuel et al., 2002). Some researchers have found positive effects of laptop use on student achievement (Gulek & Demirtas, 2005; Kposowa & Valdez, 2013; Lowther et al., 2003; Rosen & Beck-Hill, 2012), and others found non statistically significant or negative effects (Angrist & Lavy, 2002; Shapley et al., 2010; Suhr et al., 2010). Similarly, in a recent meta-analysis of seven studies of 1:1 implementations in mathematics and their effects on student achievement conducted since 2005, the researchers found four studies with positive effects on student achievement, two studies with no effect, and one study with negative effects; overall, in all subject areas, “the number of studies identified that deployed rigorous experimental or quasi-experimental methods was small, making meta-analysis difficult, and making it impossible for us to conduct moderator analyses” (Zheng, Warschauer, Lin, & Chang, 2016, p. 1076).

The next three sections address student achievement and assessments from different perspectives. Section 2.6.1 focuses on measurable changes in the classroom, as addressed qualitatively in this current study, and Sections 2.6.2 and 2.6.3 discuss the history of assessments in the State of New York and the assessments addressed quantitatively in this current study, respectively.

### **2.6.1 Classroom Assessments**

When judging the success of schools, “progress is among the most critical dimensions” (Hattie, 2012, p. 66). Progress is a product of both the teacher, who designs and implements the learning environment, and the student, who is responsible for the learning within the established environment (Black & Wiliam, 2009). Classroom assessments and other tests administered to measure student achievement have been classified as ‘formative’ or ‘summative’ based upon the time they were administered and the way in which the test results were interpreted (Hattie, 2012; Popham, 2008).

The definition of formative assessments is complex and often contains the following concepts: a planned process to elicit, interpret, and use assessment evidence of student achievement to adjust and move forward teachers' instruction and students' learning practices (Black & Wiliam, 2009; Brookhart, 2013; Hattie, 2012; Popham, 2008). In addition, Black and Wiliam (2009) include the role of peers in the process of eliciting, interpreting, and using the assessment evidence and emphasize that subsequent instructional decisions would be better founded, than decisions that would have been made in the absence of the evidence that was elicited.

Although formative assessments provide insight into student achievement, "most of the available resources and most of the public and political attention were focused on national external tests" (Black & Wiliam, 1998, p. 5). Designed properly, summative assessments can require students to use higher-order thinking skills, communicate what is valued in the discipline, and offer feedback to move learning forward (Black & Wiliam, 2009; Brookhart, 2010).

Unfortunately, not all standardized summative assessments are designed this way, and this may contribute to why studies using non-standardized tests to measure mathematics achievement report larger effects of technology on mathematics achievement than studies using standardized tests as measurement tools (Li & Ma, 2010). It has been argued that the inquiry and problem solving skills facilitated by laptop use are not accurately measured by current versions of standardized tests (Suhr et al., 2010).

### **2.6.2 History of New York State Mathematics Assessments**

As noted earlier, whether or not there is a correlation between laptop initiatives and increased student achievement based on standardized tests has been inconclusive. Despite all the massive investments and state-legislated initiatives to 'revolutionize' education, the overall impact of 1:1 programs remains unclear (McLester, 2011). There is simply not enough conclusive data to show that 1:1 computing programs impact student performance on standardized measures.

In response to increasing political, economic, and technological complexities, problem solving has become an educational and testing focal point (Gerver, 2004), and the NYSE have morphed accordingly. The challenge for the test designers was to create an authentic assessment of problem solving skills within the confines of a standardized test to be administered to a diverse student population. Tucker and Stronge (2005, p. 18) stated that as far as norm-referenced achievement tests, such as the NYSE, are concerned, considerations needed to be made that “include content validity (e.g., proper match between the test and the subject matter taught), the test ceiling (e.g., the test should not be too easy for students), and related issues.” Although matching the assessment to the curriculum was a straightforward task accomplished daily by teachers in the classroom, doing so while taking into account appropriate difficulty for a wide range of learners with varied backgrounds and special needs added complexity to this task.

In 1966, New York State introduced its first standardized mathematics test in the elementary schools, namely the grade 3 Pupil Evaluation Program (PEP) Test in mathematics. In 1999, a standardized mathematics test was introduced in grade 4. In 2002, No Child Left Behind took effect and grades 3-8 tests in mathematics were administered in 2006. In 2013, the grades 3-8 mathematics tests were realigned to the Common Core Curriculum (New York State Education Department, 2014b). As mentioned in Chapter 1, the NYSE has continued to be redesigned to more accurately determine students’ success in meeting the state standards. Winerip (2011) documented the history of politics and testing in New York State from December 2002 through December 2011. A pattern of short-lived use and criticism was shown to coincide with major political elections. The grades 3-8 tests in mathematics and English Language Arts were introduced in 2006 to address the need to make schools accountable for all students. In June 2009, progress in student assessment was claimed during the mayoral election but declared artificially inflated by the chancellor of the Board of Regents in June 2010 (Winerip, 2011). In August 2011, the mayor again declared that scores were moving in the right direction but by November 2011 the Commissioner of Education admitted a decline in performance (Winerip, 2011).

As of 2011, the pattern stopped as the whole assessment system was reevaluated, but the political involvement did not. In 2013 the State of New York introduced state assessments in grades 3-8 mathematics and English Language Arts based upon the Common Core State Standards. The Common Core State Standards also had political beginnings, as the initial

funding and commission to create “a shorter list of standards that emphasize deeper instruction of key concepts” came from the Bill and Melinda Gates Foundation and the National Governors Association (Rix, 2013, p. 27). However, these standards were poorly received by many teachers and school administrators because they did not originate from within the state education departments and thus were perceived to lack validity.

According to the New York State Education Department (2014a, p. 1), all questions on the 2014 NYSE were vetted by independent evaluators, including teachers. Evaluators consistently found that the items on the tests measure the Common Core with fidelity and are fair measures of student achievement. Additional claims were made that questions were included “that require students to show understanding of mathematics procedures, as well as problems that require students to demonstrate their conceptual understanding as well as their ability to apply mathematics” (New York State Education Department, 2014a, p. 10). These claims, however, have been consistently refuted by parents and educators alike because the test creators were perceived as too far removed from the classroom and teachers did not participate in the generation of the assessments (Baker, 2014).

The future of educational testing in the state of New York remains one of the most divisive, politically motivated issues in the state. On the one hand, Ward (2015, p. 1), Superintendent of the Gates Chili Central School District, stated that, although flawed, the NYSE results still provide valuable information to inform instructional practices and facilitate student learning. On the other, Calkins, Ehrenworth, and Lehman (2012, p. 4) assert “The very premise that decisions about kindergarten curriculum should be based upon a study of what college students do is questionable.” In September 2015, Cuomo (2015), governor of the State of New York, released a statement that acknowledged that the current Common Core program in New York is not working and must be fixed. In reaction to the governor’s rhetoric, Infante (2016) sent a memo in January 2016 to district superintendents and other leaders throughout New York State calling for changes in the test development and administration including greater educator involvement in the design of the assessments in conjunction with a new vendor Questar Assessment, fewer test questions, and untimed assessments for all students. Hopefully, future common core assessments will take on the form envisioned by Dessoff (2012, p. 54, 56) where the assessments “will test students on practices such as making sense of problems, reasoning abstractly and quantitatively, constructing viable arguments and critiquing the reasoning of others, modeling with mathematics, using appropriate tools

strategically, communicating precisely, and looking for and making use of structure.” These types of questions would hopefully appease those on both sides of the debate, as they would measure the heart of the mathematics being taught in the classrooms.

For a brief history of the NYSE and the content, format, and scoring of the 2010 and 2011 New York State Mathematics Assessments, see Appendix E, F, and G. Appendix E describes the curriculum and how it was assessed by the 2010 and 2011 NYSE. Appendix F offers the test configuration tables for the 2010 and 2011 NYSE. Finally, Appendix G provides the content strand breakdown for the 2010 and 2011 NYSE.

## **2.7 Summary of the Chapter**

This chapter reviewed literature regarding: mathematics learning environments; constructivist, problem solving, and small group approaches within those learning environments; technology use in elementary education, including laptop initiatives, the role of the teacher, and the enVisionMATH program; students’ attitudes towards mathematics and instruments used to study them; and formative assessments and the NYSE. The primary focus of this review was to examine the outgrowth of laptop initiatives from other learning environments research and how changes in attitudes and student achievement could be measured in technology-enhanced mathematics learning environments. Secondly, the mathematics curriculum and NYSE offered in the Lynbrook Union Free School District were expounded. The reviewed literature show that:

- Student feedback can provide valuable insight into classroom learning environments.
- Peer-assisted learning in small groups may support students as they construct mathematical knowledge and problem solve.
- Technology-enhanced learning environments have the potential to support student-centered learning, if the environments are properly aligned to teaching agendas.
- Laptops do not induce learning; teachers play critical roles in laptop learning environments and need proper professional development and support in order to be successful.
- In order to reach the full potential of laptop computing environments, laptops must become an integral part of the learning environment and classrooms must continuously change based upon feedback (Weston & Bain, 2010).

- Learning environment tools may offer insight into teaching and learning that may otherwise be missed.
- Formative assessments should generate discussion and further the construction and refinement of collective knowledge by encouraging learners to reflect on their own learning processes and understanding (Black & Wiliam, 2009).

The New York State Assessment system has flaws and may be influenced by politics; however, it can help guide instruction in New York State and allow for summative comparisons of teaching and learning. Laptops in the elementary mathematics classroom have potential to support student-centered learning and transform learning environments. The ultimate goal is to create ‘self-organizing schools’ that focus on producing measurable academic and social gains through cycles of feedback and differentiated learning opportunities (Weston & Bain, 2010). Further research in well-designed laptop environments will continue to illuminate the path to success.

## CHAPTER 3

### RESEARCH METHODOLOGY

#### 3.1 Introduction

This chapter outlines the research methodology used in this study, including: research questions, research design, student sample, quantitative and qualitative data collection procedures, triangulation, quantitative and qualitative analyses, and a summary.

The sections begin with the introduction in Section 3.1. Section 3.2 presents the research questions and Section 3.3 follows with the research design, which includes the school setting and the teaching intervention. The student sample is defined in Section 3.4. Next, the quantitative data collection procedures are put forth in Section 3.5 where the instruments used are also fully described. Section 3.6 explains how observations were conducted and distributed and what form was used for data collection. The purpose for collecting various quantitative and qualitative data sources is offered in Section 3.7. The quantitative analyses in Section 3.8 entail: the reliability and validity of the instruments, the NYSE scores, and statistical analyses. Section 3.9 follows with similar qualitative analyses. Finally, Section 3.10 combines both the quantitative and qualitative analyses, and Section 3.11 summarizes the chapter.

This research study was designed to examine the potential benefits of introducing a 1:1 versus a 2:1 laptop program to fourth and fifth grade mathematics students. The study examined students' perceptions of both models including fostering a positive learning environment, improving students' attitudes towards the subject, and increasing academic achievement. This work is important because there has been little evidence in educational literature or in practice to demonstrate the effectiveness of any reforms at a significant scale, including student-centered technology enhanced learning environments (Weston & Bain, 2010). This study attempts to make a small contribution to the field by further exploring 1:1 computing environment in elementary mathematics and examining the fresh perspective of the 2:1 computing model.

### **3.2 Research Questions**

As mentioned in the previous section, this research study was constructed in such a way as to take a close look at 1:1 and 2:1 computing environment and compare their potential benefits for elementary fourth and fifth grade mathematics students. The research questions were formulated to provide a framework for the investigation.

1. Are there differences in students' perceptions of their learning environments when studying in 1:1 or 2:1 computing environment?
2. Are there differences in students' mathematics attitudes when studying in 1:1 or 2:1 computing environment?
3. Are there statistically significant correlations between the learning environment scales, students' mathematics attitudes, and mathematics achievement when studying in 1:1 or 2:1 computing environment?

### **3.3 The Research Design**

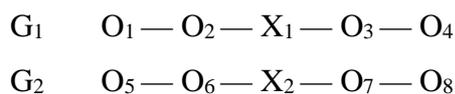
A pretest and posttest design was employed to measure attitudes and achievement. This design has been used to compare groups receiving different experimental treatments in order to determine their differences via quantitative measures (Anderson & Arsenault, 1998; Dimitrov & Rumrill, 2003). As noted in Section 1.1, the study evaluated the learning environment using a pre-posttest comparison of the two students to one laptop computing model (2:1 computing) compared to the traditional one student to one laptop computing model (1:1 computing). In the 2:1 computing model, students were expected to work collaboratively on their shared laptop, while in the 1:1 computing model, students were expected to work independently on their own laptops, regardless of whether or not they were working in collaborative groups. These expectations were consistently observed in both the 2:1 and 1:1 computing classes.

Since participants in this study each received different treatments, namely either a 1:1 or 2:1 computing environment, this study did not have a traditional control group, but rather a comparison group. Although the study did not fit the traditional control group model, there was a temporal distance that separated the collection of the posttest measurement from the pretest measurement (Bonate, 2000; Campbell & Stanley, 2015; Chambliss & Schutt, 2015).

Threats to external and internal validity, such as the Hawthorne effect and mortality threats, are discussed further in Section 5.3.1.

Technically, the design used in this research study was a nonrandomized control group pretest-posttest design (Dimitrov & Rumrill, 2003). The nonrandomized control group pretest-posttest design examines preexisting groups, such as classes, and does not allow for randomization of the students receiving treatments, which is common in educational research. The benefit of this quasi-experimental research design is that it utilized the natural structure of the schools and does not interfere with the daily discourse of instruction, while still allowing for a scientific comparison (Campbell & Stanley, 1963). By the nature of the design, selection bias is introduced, an additional threat to internal validity, caused by possible differences in the students that were not mitigated by a random selection process (Cohen, Manion, & Morrison, 2011). However, there is a higher degree of external validity, since the natural setting is not disrupted and students may be unaware that they are taking part of a research study (Dimitrov & Rumrill, 2003).

The design featured studying multiple outcome variables with student learning in either 1:1 or 2:1 computing classrooms; to start, multiple variables were measured, i.e. classroom learning environment, attitude and achievement variables, and the change in the effect of each variable was calculated. Figure 3.1 illustrates the comparison group design.



*Figure 3.1* Diagram of the comparison group design

Group 1 (G<sub>1</sub>) consisted of students enrolled in three 1:1 computing classes, one from each of the following three elementary schools in the local school district – Marion Street Elementary School, Waverly Park Elementary School, and West End Elementary School. Group 2 (G<sub>2</sub>) consisted of students enrolled in nine 2:1 computing classes, three classes from Marion Street Elementary School, four from Waverly Park Elementary School, and two from West End Elementary School. The details of these settings are presented in Section 3.3.1. The 2010 NYSE (O<sub>1</sub> and O<sub>5</sub>) were administered to both groups in May 2010. Students in both groups completed the WIHIC and TOMRA (O<sub>2</sub> and O<sub>6</sub>) in December 2010. Also, in December 2010, students included in G<sub>1</sub> began instruction in the 1:1 computing environment (X<sub>1</sub>), and

students included in G<sub>2</sub> began instruction in the 2:1 computing environment (X<sub>2</sub>). In May 2011, both groups were administered the 2011 NYSE (O<sub>3</sub> and O<sub>7</sub>). Finally, in June 2011, students in both groups completed the WIHIC and TOMRA (O<sub>4</sub> and O<sub>8</sub>) for a second time.

### **3.3.1 The School Setting**

The Lynbrook Union Free School District is a community of approximately 20,000 people located on the South Shore of Long Island in the State of New York; it encompasses parts of the Village of Lynbrook, Hewlett, Hewlett Harbor, East Rockaway as well as small portions of Malverne and Valley Stream. The Lynbrook School District has an enrollment of approximately 2,798 students. There are three elementary schools (Marion Street Elementary School, Waverly Park Elementary School, and West End Elementary School, grades 1-5), two middle schools (North and South Middle Schools, grades 6-8), one high school (Lynbrook High School, grades 9-12), and one Kindergarten Center. According to the last school report card (New York State Education Department, 2016a), 52% of the students were male and 48% of the students were females. By ethnicity, the student distribution was 3% Black or African American, 14% Hispanic or Latino, 5% Asian or Native Hawaiian/Other Pacific Islander, 76% White, and 1% Multiracial. Finally, 1% of the students are Limited English Proficient<sup>2</sup> Students, 13% are Students with Disabilities, and 12% are Economically Disadvantaged Students.

All three grades 1-5 elementary schools included in this study offer similar curricula and programs; all three were provided similar laptop programs and all elementary mathematics classes had the enVisionMATH program as an available resource. All schools have academic intervention services, special education resource rooms, and a gifted and talented program. In addition, Marion Street Elementary school hosted additional special education classes, namely two self-contained classes as well as approximately two integrated co-teach classes per grade level, and West End Elementary School hosted all of the English as a Second Language classes.

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<sup>2</sup> Limited English Proficient Students are students for whom English is not their first language.

Marion Street Elementary School housed approximately 429 students serviced by 41 highly qualified<sup>3</sup> teachers. Waverly Park Elementary housed approximately 217 students serviced by 14 highly qualified teachers. West End Elementary housed approximately 402 students serviced by 33 highly qualified teachers. The reason that Marion Street had such a low student-teacher ratio compared to the other two schools was due to the special education classes that this school offered which the other two schools did not. Despite the number of teachers in the rooms, there were approximately 20 students in each fourth and fifth grade class.

All of the district schools were deemed as “In Good Standing” by the New York State Education Department. Although the NYSE tests used in this study were administered in May 2010 and May 2011, the results were not reported to the students and their families until September 2010 and September 2011, respectively. Tables 3.1 and 3.2 show summaries of the performance of each of the Lynbrook elementary schools as compared to New York State averages for each of the assessments included in the study. The percent passing in each of the Lynbrook elementary schools was higher than the state mean for all testing years and grade levels.

*Table 3.1* 2010 New York State Assessment results

NYS Assessment	Group	Total Tested	Percent Passing	Percent Mastery
Grade 3 Math	Marion Street	96	81%	46%
Grade 3 Math	Waverly Park	41	98%	68%
Grade 3 Math	West End	85	60%	20%
Grade 3 Math	New York State	198,665	59%	24%
Grade 4 Math	Marion Street	88	94%	53%
Grade 4 Math	Waverly Park	53	100%	68%
Grade 4 Math	West End	87	89%	44%
Grade 4 Math	New York State	201,634	64%	26%

<sup>3</sup> Highly qualified is a technical term used by the New York State Education Department to denote that a teacher has completed the certification requirements for the subject being taught. No further information regarding the teachers’ qualifications can be provided as per an agreement with the teachers’ union.

Table 3.2 2011 New York State Assessment results

NYS Assessment	Group	Total Tested	Percent Passing	Percent Mastery
Grade 4 Math	Marion Street	96	78%	40%
Grade 4 Math	Waverly Park	43	100%	56%
Grade 4 Math	West End	80	91%	51%
Grade 4 Math	New York State	199,327	67%	27%
Grade 5 Math	Marion Street	92	85%	36%
Grade 5 Math	Waverly Park	52	96%	54%
Grade 5 Math	West End	86	84%	27%
Grade 5 Math	New York State	202,595	66%	23%

### 3.3.2 enVisionMATH

Although formative assessment data was not available to the researcher in this current study, the formative assessments were observed and discussed as part of the observation process in the classrooms. As mentioned earlier, the enVisionMATH program provided assessments that could be used to collect both formative and summative data, allowing teachers a measure of incremental growth.

Choosing a curriculum is a very important decision to make and should not be taken lightly. Costa and Kallick (2000, p. 13) designated that “curriculum is the pulse of the school. Curriculum can also be considered the currency by which teachers exchange thoughts and ideas with students and the broader community.” After working with a committee of teachers, administrators, and parents, and meeting with several vendors and evaluating their products, the Lynbrook School District selected the enVisionMATH program which was marketed as having five major strengths: conceptual understanding, problem solving, understanding by design, meeting individual needs, and program organization (Pearson Education, 2011). To promote conceptual understanding, mathematical concepts are presented visually and lessons contain interactive components. The videos and visuals were designed to teach mathematics beyond the confines of a traditional textbook; children could watch mathematics being developed in an interactive environment. The resources were created to encourage a problem solving approach entrenched in investigation, allowing students to explore real world situations and communicate mathematical ideas. The first five minutes of each lesson were meant to be committed to problem based interactive learning, allowing the teacher to assess the students from the start of the lesson and prescribe the

remainder of the lesson accordingly. Small groups were recommended to allow students to debate mathematics and engage in hands-on learning activities (Terrell, 2015).

The enVisionMATH program offered a collection of constructed lessons and supplemental materials that hone specific mathematical skills and concepts (Pearson Education, 2011). This worked in conjunction with the data collection features that were available before, during, and after each and every lesson. Students' areas of weakness were able to be identified through these topical online assessments, etc., and appropriate remediation or enrichment was automatically provided to meet individual student's needs. The program design was constructed to ideally meet students at their current levels of understanding and systematically offer opportunities to deepen their understanding and application of essential math concepts, as recommended by Schmoker (2011).

The enVisionMATH program was organized into units that offer a variety of resources for teachers to try many different types of multisensory approaches, including some that were technology based (Pearson Education, 2011). According to What Works Clearinghouse, enVisionMATH consists of approximately 130 daily lessons per grade level (Pearson Education, 2011). The components of the lessons include: review materials, small group, problem-solving explorations, and guided and independent practice. Also, assessments accompany each lesson that can be used to determine which students would benefit from targeted practice and other support activities. Lessons are designed to be flexible and allow teachers to decide the sequence in which they are taught and what resources, texts, workbooks, manipulatives, and technology, would be most appropriate for their students (Institute of Education Sciences, 2013).

Before considering a laptop program implementation, the Lynbrook School District wanted to find a mathematics program that would support its teachers in transforming teaching and learning. During the evaluation process, the District committee determined that the visual and interactive components of enVisionMATH provided students with additional access points to mathematical concepts. The digital and print materials were synchronized in such a way as to allow for meaningful simultaneous station work, helping promote small group instruction (Pearson Education, 2011). Resendez, Azin, and Strobel (2009) found that teachers using the enVisionMATH program to support their instruction felt more prepared than the teachers in the control group to: encourage students to solve problems in various

contexts, prepare lessons that support student investigation, encourage students to discover multiple mathematically sound approaches, and use a variety of measures to gauge student learning. The tutorials, games, and other digital components appeared to: engage the students, make data available to the teachers, allow for differentiation, and enhance explanations with motion and sound. This was consistent with the enVisionMATH program design to connect guided practice to interactive learning (Pearson Education, 2011). This was important since the Lynbrook School District was searching for additional instructional support and data analysis. The center activities were also enticing because they provided teachers with tools to deepen student understanding (Resendez et al., 2009).

### **3.3.3 The Teaching Intervention**

All classes had access to similar teaching methodologies and technologies, as determined by the principals' regular weekly informal observations and bi-weekly monitoring of lesson plans. In addition, the staff had received the same staff development. All of the teachers involved in the study have been deemed highly qualified (see note on page 35) by the New York State Education Department, and all were trained in the enVisionMATH program and its technological components. Members of the enVisionMATH professional development team provided an initial overview workshop explaining the program and how to properly implement it in the classroom to the Lynbrook teachers. To provide daily onsite support, the district-wide instructional technology specialist in Lynbrook was trained as well and was present in classrooms on an as-needed basis. The role of the district-wide instructional technology specialist provided both curricular and technical support to teachers and students, as they transitioned from strictly traditional print materials to interactive online components. The district-wide instructional technology specialist also assisted teachers in the planning process to include more student-driven technological elements, and in the instructional process, as these fourth and fifth grade students were introduced to daily laptop technology in their classes for the first time.

Although mathematics was the primary initial focus, due to the implementation of the enVisionMATH program, the laptops were utilized by the students throughout the school day for all subject areas. The majority of classrooms, seven at both Marion Street and West End Schools and four at Waverly Park School, were assigned to 2:1 computing environments, and one class per building was selected to learn in a 1:1 computing environment. Since the

laptops were new to all of the students involved, there was a distinctive opportunity to measure student growth in all areas and to compare the two interventions. The observed features of the 1:1 and 2:1 computing environments, are described in brief in section 3.6.2 and detailed throughout chapter 4 based on the agreed upon field notes of the researcher and the Lynbrook UFSD Director of Technology, were also corroborated as ‘typical’ by the supervising principals, as an additional measure to gauge fidelity.

### **3.4 Student Sample**

Since the researcher is employed by the Lynbrook Union Free School District, extra precautions were taken so that teachers and students would not feel pressured into participating in the study. First, permission was obtained from each of the building principals to conduct the study in her building; a representative information sheet and consent form sent to one of the principals is found in Appendix H. Next, the Elementary Vice President of the Lynbrook Teachers’ Association was approached to solicit faculty volunteers. Those teachers who wished to participate, four from Marion Street School, five from Waverly Park School, and three from West End School, were then asked for student volunteers to be part of the study, and permission slips were sent home for both the parents and students to sign if they desired to participate. Copies of the parent and student information sheets and consent forms are located in Appendix I and Appendix J, respectively.

In order to assess the impact of this emerging technology, the TOMRA and WIHIC were administered in December 2010 before the interventions and in June 2011 after the interventions to see if the responses significantly differed. Additionally, two years of scores on the NYSE were compared to examine impact upon achievement. Any student who did not have a complete data set was excluded from the study.

As mentioned in the previous section, the students involved in the study had previously learned mathematics in classrooms with limited computer access, approximately two desktop computers, during the 2009-2010 school year prior to the study and were assigned laptops during the study either on a 1:1 or 2:1 basis depending upon the class in which they were enrolled. In this study, 35 students studied in the 1:1 computing learning environment, and 89 students studied in the 2:1 computing learning environment. Since the researcher supervises in the Lynbrook Union Free School District, further disaggregation of the data was

limited to protect all student and teacher participants. Students were solicited from all three buildings learning in both the 1:1 and 2:1 computing environments, but the building breakdown is unavailable so as not to be identifiable. Furthermore, the assignment of participants to classes, and therefore their computing environment, was done by the building principals in their usual manner during the summer of 2010. The potential impact of these unknown issues are discussed further in Section 5.3.1.

During the classroom observations, random teachers and students included in the study provided qualitative information as well. Again, in order to protect the identities of all parties involved, the data collected are only presented in aggregate form so as not to identify any teachers or students.

### **3.5 Quantitative Data Collection Procedures**

In order to address the research questions posed in Section 3.2, multiple sources of quantitative data were collected. First, pretest-posttest data regarding students' attitudes in both the 1:1 and 2:1 computing elementary mathematics learning environments were obtained via the WIHIC and TOMRA, and as noted in Sections 2.5.1 and 2.5.2 respectively, both instruments have been shown to be valid and reliable with this age group and hence were chosen. Second, the students' scores on the NYSE were collected to measure academic achievement. For the fourth graders, the 2010 New York State Third Grade Mathematics Assessment served as the pretest for the 2011 New York State Fourth Grade Mathematics Assessment, and for the fifth graders, the 2010 New York State Fourth Grade Mathematics Assessment served as the pretest for the 2011 New York State Fifth Grade Mathematics Assessment. The attitudes and achievement of students in the 1:1 and 2:1 computing learning environments were compared using these multiple sources of information.

#### **3.5.1 What Is Happening In this Class?**

In December 2010, the 124 students involved in the study completed the WIHIC (Aldridge et al., 1999). 35 of those students were then introduced to a 1:1 computing environment and 89 of those students were introduced to a 2:1 computing learning environment and were re-administered the questionnaire approximately six months later. As mentioned in Section 1.5, a copy of the questionnaire can be found in Appendix C.

Items from the following seven scales of the WIHIC were measured: Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity.

*Table 3.3* Description and sample items for each scale of the WIHIC used

Scale Name	Description	Sample Items
Student Cohesiveness	Connection to peers	I work well with other class members.
Teacher Support	Teacher's interaction with individual students	The teacher talks with me.
Involvement	Student participation	I discuss ideas in class.
Investigation	Inquiry based learning	I solve problems by using information obtained from my own investigations.
Task Orientation	Attention to task	I try to understand the work in this class.
Cooperation	Student support system	I learn from other students in this class.
Equity	Equal access to resources	I get the same opportunity to answer questions as other students.

Eight items from each scale were included in the data analysis, except for Student Cohesiveness for which five were included. Items three, four, and eight from the Student Cohesiveness scale were excluded due to low inter-item correlations on the pretest. Each item was positively worded and students responded on a five point Likert scale. The choices were almost never (1), seldom (2), sometimes (3), often (4), and almost always (5). Table 3.3 illustrates the scales.

### **3.5.2 Test of Mathematics-Related Attitudes**

Similarly, in December 2010 and June 2011, the 124 students involved in the study, 35 students learning in a 1:1 computing environment and 89 students learning in a 2:1 computing learning environment, completed the TOMRA (Fraser, 1981). As mentioned in Section 1.5, the modified survey administered to the students can be found in Appendix B.

The TOMRA survey is an adaptation of the TOSRA, and in this study, items from the following three scales were measured: Attitudes Towards Mathematics Inquiry, Adoption of Mathematics Attitudes, and Enjoyment of Mathematics Lessons. Ten items from each scale were included in the data analysis. There were positively and negatively worded items and students responded on a five point Likert scale. For the positively worded items, the choices were scored as follows: strongly agree (5), agree (4), not sure (3), disagree (2), and strongly disagree (1); for the negatively worded items, the scoring is reversed. Table 3.4 illustrates the three scales with sample items.

*Table 3.4* Description and sample items for each scale of the TOMRA used

Scale Name	Description	Sample Items
Attitudes Towards Mathematics Inquiry	Desire to derive own knowledge	I would rather agree with people than investigate a problem to find out for myself.
Adoption of Mathematics Attitudes	Openness to new ideas	I am curious about the world in which we live.
Enjoyment of Mathematics Lessons	Interest in mathematics	Mathematics lessons are fun.

### 3.5.3 New York State Mathematics Assessments

The New York State Education Department conducted annual tests in the area of mathematics, in compliance with the No Child Left Behind Act, in grades 3 through 8. Similarly, in May 2010, these assessments were administered across the state over a two-day period for grade 3 and a three day period for grade 4. In May 2011, the mathematics assessments were administered across the state over a two-day period for both grades 4 and 5. All examinations were given raw scores that were converted to scale scores that were equated to performance levels 1-4, 4 being the highest and 1 being the lowest. Students who scored 3 or better were considered proficient for accountability purposes, and those who scored 4 were considered to have mastered the material.

The students attending the Lynbrook Union Free School District have traditionally performed well on these assessments and these years were no different, as evidenced by the results shown in Tables 3.2 and 3.3. The NYSE scores serve as accountability measures for both the schools and students because schools that consistently do not meet their targets receive

intervention from the state and students who are not proficient receive academic support services the following school year. Parents are notified of their students' scores and corresponding academic program at the start of the following school year.

### **3.6 Qualitative Data Collection Procedures**

Multiple observations were conducted in the participating Lynbrook Public Schools by both the researcher and the Lynbrook UFSD Director of Technology. In order to prevent data from being connected to specific teachers and students, pre-observation, observation, and post-observation data was collected and compiled. Data sources include conversations with the teachers, students, and what was directly observed during the lessons.

Both observers' field notes were collected and coded using the Danielson Rubric. As mentioned previously, this rubric is typically used for evaluative purposes in the district, and included all conversations with teachers and students which happened naturally during the observation process. Both observers had received ongoing reliability training through the Lynbrook Public Schools on the use of this rubric, as functions of their employment. Upon hire, both observers received an initial Danielson Rubric training, and the follow up internal interrater reliability trainings required on a yearly basis for the entire administrative staff. Approximately 95% of the field notes were in agreement, and those that were not were discarded. The qualitative data collected by the observers were used to provide further insight into the research questions and this is described later in section 3.7.

#### **3.6.1 Danielson Rubric**

In order to assess its teaching staff, the Lynbrook Union Free School District developed a three category (satisfactory, needs improvement, and unsatisfactory) observation form based on Danielson's Framework of Teaching; this form is included as Appendix A. Although the framework has four domains: (1) Planning and Preparation, (2) The Classroom Environment, (3) Instruction, and (4) Professional Responsibilities, only the first three domains were deemed observable during an individual lesson and appear in the Lynbrook UFSD observation form (Danielson, 2007). Appendix K illustrates the composition of the entire rubric and how each of the domains is further defined by either 5 or 6 components, for a total

of 22 components. These components are descriptions of specific aspects of teaching that when combined offer comprehensive insight into the overarching domain.

The purpose of this framework for teaching was and remains to develop a learning environment conducive to student learning. Danielson (2007) claimed that the framework of teaching was versatile enough to be used for activities such as: preparing, recruiting, and hiring new teachers, guiding new, veteran, and struggling teachers, and communicating the school vision to the community at large.

Danielson (2007) acknowledged that her framework was not the only comprehensive description of exemplary teacher practice; however, it does attempt to define what professional teachers should know and be able to do. The framework described the teaching and learning process from planning the classroom environment and instruction through meaningful reflection. Since all of these aspects of the teaching profession, both inside and outside of the classroom, were included, the framework was useful for pre- and post-conferences, as well as lesson observations themselves.

Danielson (2007) described each of the four domains and their relationship to teaching and learning. The first domain was primarily about the preparation necessary for classroom instruction; particular attention was paid to lesson construction, so that learning would not be left to chance. The second domain discussed how to create a learning environment that is free of distractions, so that students could feel safe and welcomed in order to be able to fully participate in class. Danielson (2007, p. 77) believed that “Domain 3 is the heart of the framework for teaching; it describes, after all, the critical interactive work that teachers undertake when they bring complex content to life for their students.” The focus of this domain was how well teachers instruct and guide their students to the point where they can become independent learners. Finally, the fourth domain described meaningful reflection that could be used to inform future teaching practice.

Several core beliefs were embedded in the framework for teaching including but not limited to: what constitutes important learning for students defines teaching, good teaching is based upon a constructivist approach, the purpose of the lesson must be the center of all instruction, and student engagement in well-designed lessons ensures learning (Danielson, 2007). Of these beliefs, the most fundamental, pervasive, and strongest belief statements seems to be

the following, “Although not universally accepted throughout all of the 20th century, constructivism is now acknowledged by cognitive psychologists as providing the most powerful framework for understanding how children (and adults) learn (p. 15).”

Since Danielson’s beliefs were aligned to the New York State Education Department’s expectations for teaching and learning, the Danielson Rubric was state approved for teacher observations. According to Milliken (2011) in the Teacher and Principal Practice Rubric Providers Technical Proposal – Application for the Danielson’s framework submitted to the New York State Education Department, Danielson’s Framework for Teaching was initially validated by Educational Testing Service and its validity was confirmed by subsequent studies, including one conducted by the Consortium for Policy Research in Education. The approval of the Danielson rubric for teacher observation in New York State reflects that the New York State Education Department (2016b) accepted the rubric’s validity and reliability based upon validation by the Educational Testing Service and the Consortium for Policy Research in Education. In addition, a study, including 118 mathematics teachers in the Cincinnati Public Schools, found statistically significant correlations between teachers’ composite evaluation ratings using Danielson’s Framework for Teaching and students’ mean gains on the 3-8 mathematics state assessments and district-created examinations mirroring those assessments was 0.383 in the first year and 0.379 in the second year of implementation, the highest correlations in the four academic subject areas studied (Holtzapple, 2003).

By setting measurable targets and professing to high standards, Lynbrook Public Schools made a strong statement about its core values and offered an established structure for to assess teachers’ professional practice and to use the data collected to improve teaching and learning. Danielson (2007, p. 14) stated that her framework has the “power to elevate professional conversations that characterize the interaction of exemplary teachers everywhere,” and Lynbrook Union Free School District has certainly benefited from this. A powerful outcome of using the framework throughout the District has been a continuous cycle of teaching and reflection.

Danielson’s ideas have been responsible for noticeable continuities of improved instruction throughout the Lynbrook Public Schools. Teaching activities throughout the District contain elements of problem solving and allowing students to work collaboratively to construct their own knowledge and understanding (Danielson, 2007). Consistent with Danielson’s (2007)

theoretical description, students in the Lynbrook Public Schools appear enthusiastic and committed to learning because they adopt responsibility for their own learning and that of their peers. Through the process of doing, students seem to have internalized the concepts being taught, which may in part be due to emphasis on action verbs and the subsequent learning environments that these words promote using Danielson's Framework of Teaching.

### **3.6.2 Classroom Observations**

As mentioned in section 3.6.2, the Lynbrook Union Free School District used a modified form of the Danielson framework to evaluate its teachers' performance, which can be found in Appendix A. Danielson (2007) emphasized the importance of classroom observations to measure how well teachers are able to implement the 'research-based definition of good teaching' outlined in the Framework for Teaching. Both observers, the researcher and the Director of Technology, trained in the Danielson rubric knew what evidence to look for in conjunction with each of the components. Table 3.5 illustrates the observation elements from the Lynbrook UFSD observation form, based upon the Danielson rubric, that are most associated with items included in the TOMRA and WIHIC instruments used in the study.

*Table 3.5* Associated elements from the Lynbrook UFSD observation form and items from the TOMRA and WIHIC used

Element	TOMRA Item Numbers	WIHIC Item Numbers
Provides a variety of activities and/or instructional strategies	4, 5, 7, 13, 16, 19, 20, 22, 25, 28	22, 23, 25, 27, 29, 32, 41, 44, 45, 46
Engages students and sustains interest in the lesson	2, 3, 6, 10, 12, 17	17, 18
Employs effective questioning which promotes understanding	1, 26	16, 19, 21, 24, 30, 31
Provides a safe, orderly, and productive learning environment which emphasizes the importance of content and expectations for learning and achievement	6, 11, 15	5, 6, 7, 33, 36, 39, 40, 47, 48
Utilizes classroom management techniques to create an atmosphere of mutual respect, purpose, and equity	14, 29	11, 38, 43, 51, 52, 54, 56

Note: See Appendices B and C for the full items of TOMRA and WIHIC

Since teachers were routinely observed in this fashion throughout the district, use of the Lynbrook UFSD observation form was comfortable for them and their students with minimum disruption of the learning environment. In April 2011, a total of 18 observations were conducted, two in each of the participating classes in the 1:1 and 2:1 computing environments. During the observations, both observers walked about the classroom, observing all aspects of the learning environment and asking questions and engaging students in dialogue when deemed appropriate. Students and faculty members spoke openly and freely with the observers regarding the learning environment, and the observers witnessed different types of technological implementations to be discussed further in section 4.3. This methodology is in line with a ‘naturalistic perspective’ of qualitative evaluation methods (Greene & McClintock, 1985, p. 523).

The mathematics lessons observed featured a variety of models. Some incorporated laptops as part of the station work, others utilized print materials. In other lessons students were problem solving and exploring with the laptops, either with partners or individually. Finally, other lessons incorporated the laptops as part of the formative assessment process,

administering examinations to individuals or groups of students. All of these implementations were aligned to the daily expectations of incorporating the new technologies in teaching and learning.

No matter what the main features of the lessons were, the observers' findings were separated into the following categories: Planning and Preparation, Teaching and Instruction, Student Learning and Assessment, Classroom Environment, Aspects of Teaching Performance that Contributed Most to Lesson Effectiveness, and Aspects of Teaching Performance where Improvement or Change would Contribute to Greater Lesson Effectiveness. Notes taken by both observers were compared and agreed upon results were reported. The inter-rater reliability training provided by the Lynbrook Public Schools increased the trustworthiness of the observation findings through investigator triangulation, discussed in Section 3.7 (Denzin, 1978; Leech & Onwuegbuzie, 2007).

### **3.7 Triangulation**

Multiple measures were included in this current study to provide a fuller explanation of the findings, help eliminate bias, and detect anomalies in any possible discoveries (Anderson & Arsenault, 1998; Cohen et al., 2011). As noted in the initial research design, triangulation is an important process of using multiple sources in order to corroborate findings when evaluating new teaching methods (Cohen et al., 2011; Oliver-Hoyo & Allen, 2006; Wiersma, 2000).

Of the four types of triangulation: data, investigator, theory, and methodological triangulation, investigator and methodological triangulation were essential to this current research study (Denzin, 1978; McLean, Brayley, & Rathbun, 1997). First, investigator triangulation, mentioned in the previous section, referred to the use of multiple observers (Denzin, 1978). The qualitative findings included in this study, reflect two people independently documenting the same thing. Second, methodological triangulation occurred through the collection of qualitative information in the actual context and environment where the quantitative data were collected, to possibly explain variations and strengthen the validity of the findings (Greene & McClintock, 1985). Contrasting methods, such as using questionnaires and conducting observations to observe the same phenomena, add confidence

to the research findings (Cohen et al., 2011; McLean et al., 1997; Spinner & Fraser, 2005; Tobin & Fraser, 1998).

Although quantitative data collection is important to understand the success or failure of interventions and changes in the learning environment, qualitative data collection is equally as important to understand possible underlying causes of what the data seems to show. If quantitative data were collected in isolation, the real causation and phenomena could have been missed (Jick, 1979). Fielding (2012, p. 126) added that the key is to “employ design combinations that satisfy the different epistemological warrants in play.” In order for triangulation to be effective, each of the methods need to contribute information that may be lacking in the others. Through the use of mixed methods and multiple perspectives, the information collected to study the research questions could be more balanced and comprehensive. Similar to Bebell and Kay’s (2010) use of observations and interviews to triangulate survey in their study of 1:1 computing, this current research study used the qualitative data collected by both observers to add clarity to the quantitative findings and offer answers to the research questions from different perspectives.

### **3.8 Quantitative Data Analyses**

#### **3.8.1 Reliability of the Instruments**

Kirk and Miller (1986, pp. 41-42) “identify three types of reliability referred to in quantitative research, which relate to: (1) the degree to which a measurement, given repeatedly, remains the same (2) the stability of a measurement over time; and (3) the similarity of measurements within a given time period.” Repeated, similar measurements within a range of time are critical to making meaning of results. If one of these variables was not present, results gathered by the instrument could change daily.

Past studies have shown the psychometric quality of the TOMRA (see for example, Earle & Fraser, 2016; Fraser, 1981) and WIHIC (see for example, Chionh & Fraser, 2009; Fraser et al., 2012) in terms of reliability. The Cronbach’s alpha reliabilities calculated for the 2010 NYSE ranged from 0.88–0.94 and for the 2011 NYSE they ranged from 0.91–0.94, indicating that both sets of examinations were acceptably reliable (CTB/McGraw-Hill LLC, 2010a; 2011).

### **3.8.2 Validity of the Instruments**

The validity of instruments refers to whether or not the instruments measure what they are intended to measure and determines how accurate the research results are (Golafshani, 2003). If the instruments were not valid, the results of the studies using them would be tainted. The discriminant validity, ‘unidimensionality’ and independence, of each scale of the TOMRA has been demonstrated in numerous past studies (see for example, Earle & Fraser, 2016; Fraser, 1981). Similarly, the WIHIC has been validated in international studies and studies in countries throughout the world, including numerous times in the United States (see for example, Chionh & Fraser, 2009; Fraser et al., 2012). With regards to NYSE examinations “a principal component factor analysis was conducted on a correlation matrix of individual items for each test,” included in the 2010 and 2011 NYSE, and both sets of tests were deemed unidimensional meaning that there was a common factor (ability) underlying students’ responses to mathematics test items (CTB/McGraw-Hill LLC, 2010a; 2011).

### **3.8.3 New York State Mathematics Assessments Scores**

To measure student achievement, the NYSE mathematics assessment scores were used as the pretests and posttests. Each year, the scales on the tests were reworked to reflect the difficulty level of the questions selected that year; however, the scale score range was consistent in its point allocation, even though the range changed. On the 2010 pretests, the range for the third grade assessment was 470-770 and the range for the fourth grade assessment was 485-800. On the 2011 posttests, the range for the fourth grade assessment was 485-800, and the range for the fifth grade assessment was 495-780. Since the tests were built upon constructed response theory, the scale scores were consistent to similar levels of performance. The scores from year to year were used by the New York State Education Department to determine whether or not students were making adequate yearly progress.

Table 3.6 2010 Representative Questions from the New York State Mathematics

Assessments

Assessment Questions	Grade Level	Strand
1. There were 9 people fishing at a lake. Each person caught 6 fish. What was the total number of fish caught by the 9 people? A 15 B 48 C 54 D 62	3	Number Sense and Operations
2. David multiplies 19 by 21 and gets 399. Which of these estimations could be used to check whether David's answer is reasonable? A 10 x 20 B 10 x 30 C 20 x 20 D 20 x 30	4	Number Sense and Operations
3. Heidi records the batting averages of different players on a baseball team. Which list correctly shows the batting averages in order from least to greatest? A 0.353, 0.309, 0.179, 0.172 B 0.309, 0.353, 0.179, 0.172 C 0.179, 0.172, 0.309, 0.353 D 0.172, 0.179, 0.309, 0.353	5	Number Sense and Operations

As mentioned in section 3.5.3, students' raw scores were converted to these scale scores and were then designated to performance levels 1-4, with students achieving a 3 or better being deemed proficient. Table 3.6 shows representative multiple choice and free response questions from the 2010 NYSE testing the Number Sense and Operations Strand; further representative questions from each of the other mathematical strands are in Appendix L. Questions from the 2011 NYSE were not released, but the items were similar to the 2010 assessments (CTB/McGraw-Hill LLC, 2010b; 2010c; 2010d).

### 3.8.4 Statistical Analyses

In the statistical analyses, students' learning in 1:1 computing learning environments were compared to students' learning in 2:1 computing learning environments to determine if there were any differences between the two interventions in terms of the learning environment, students' attitudes toward mathematics, and their achievement. In order to answer Research

Questions 1 and 2 and obtain results that account for pretesting differences, MANOVA, ANOVA, MANCOVA, and ANCOVA were calculated to compare the 2:1 and 1:1 classes in terms of students' learning environments and attitudes and detailed in Sections 4.2.1 and 4.2.2; in addition, a simple mean comparison was also provided. How the corresponding pretest scores for the seven scales of the WIHIC and three scales of the TOMRA were used as covariates statistically control for differences in the pretest scores is further explained in Section 4.3. In response to Research Question 3, correlations between the learning environment scales of the WIHIC and attitude scales of the TOMRA and NYSE were analyzed. Details of these analyses are contained in Sections 4.2 and in Table 3.7 in Section 3.10 which connects the research questions, data collection, and analyses.

### **3.9 Qualitative Data Analyses**

Qualitative data analyses refer to research findings that were not arrived at through statistical or other quantitative procedures (Golafshani, 2003). In typical fashion, this current research study interpreted data collected through observations and natural conversations with the participants during the observations, in order to determine if any meaningful patterns and themes emerged (Patton, 2015). This approach added context and insight into the responses to the research questions. Patton (2015, p. 1) further advised, "When in doubt, observe and ask questions. When certain, observe at length and ask many more questions." Through observation and the use of targeted questions and follow up questions, the responses to the research questions became fuller.

### **3.10 Combination of Quantitative and Qualitative Analyses**

As mentioned in section 3.7, validity concerns are why triangulation is so important. Kirk and Miller (1986, p. 13) state "Were it otherwise valueless, qualitative research would be justified solely as a validity check." Table 3.7 summarizes the quantitative data collected and analyses in response to each of the research questions. In Chapter 4, both the analyses of the quantitative measures WIHIC and TOMRA and qualitative observations are presented.

*Table 3.7 Relationship among the research questions, data collection, and data analysis*

Research Questions	Data Collection	Data Analysis
1. Are there differences in students' perceptions of their learning environments when studying in 1:1 or 2:1 computing environment?	WIHIC	Table 4.1
2. Are there differences between pretest and posttest results for student attitudes and the classroom learning environment in the 2:1 computing environment?	TOMRA	Table 4.2
3. Are there statistically significant correlations between the learning environment scales, students' mathematics attitudes, and NYSE when studying in 1:1 or 2:1 computing environment?	WIHIC TOMRA NYS Pretests and Posttests	Table 4.3

### **3.11 Summary of the Chapter**

This chapter outlined the research questions and design; student sample; quantitative and qualitative data collection, instruments, and analyses; and the triangulation of data. Two different learning environments, 1:1 and 2:1 computing, were examined using mixed methodologies to determine their impact on mathematical practices, attitudes, and achievement. Through triangulation of data sources, conclusions were corroborated.

Included in this study were 35 students from three schools learning in a 1:1 computing environment and 89 students from the same three schools learning in a 2:1 computing environment. These students all contributed pre- and post-data through completion of the WIHIC, TOMRA, and the NYSE. Students also contributed through the observation process, and some offered their own commentary through personal conversation.

## CHAPTER 4

### RESEARCH FINDINGS

#### 4.1 Overview of the Chapter

This section is a presentation of the data collected and analyzed during this research study. Included with the quantitative findings is an analysis of the qualitative data collected through the observation process. The purpose of this study was to determine the impact of a 2:1 computing environment in elementary mathematics classrooms in regards to the learning environment, student attitudes towards mathematics, and achievement in mathematics, and to compare those results to a similar 1:1 computing program. Sections 4.2 and 4.3 report the quantitative and qualitative data, respectively. Section 4.4 summarizes this chapter by combining the quantitative and qualitative data and responding to each individual research question.

#### 4.2 Quantitative Data

In order to respond to Research Questions 1 and 2, both significance test values and effect sizes are reported (Tolmie, Muijs, & McAteer, 2011). “Although methodologists have long advocated the use of some type of effect size measure, applied researchers have been slow to incorporate them along with their statistical tests in reporting their research findings” (Olejnik & Algina, 2000, p. 282). An effect size was included in this study to describe the magnitude of differences between two different environments (2:1 and 1:1) computing in elementary mathematics (American Psychological Association, 1994; Grissom & Kim, 2011; McDaniel & Fraser, 2016; Morgan, Leech, & Gloeckner, 2010; Thompson, 1999).

To analyze the data, first, MANOVA was conducted to investigate possible differences in 2:1 and 1:1 computing for the set of seven scales of the WIHIC, then again for the three scales of the TOMRA. Because the multivariate test using Wilks’ lambda criterion revealed statistically significant results in both cases, individual ANOVAs for each learning environment and attitude scale were also analyzed (Goh & Fraser, 2016; Leech, Barrett, & Morgan, 2011; McDaniel & Fraser, 2016). Effect size was measured by Cohen’s *d*, which is the difference between group means divided by the pooled standard deviation (SD) and

describes a difference in standard deviation units. Effect size was calculated in order to describe the magnitude of any differences between 2:1 and 1:1 classes for each of the WIHIC and TOMRA scales (Cohen, 1988). According to Cohen (1998), Cohen's  $d$  measures the difference between two group means divided by the average of their standard deviations and can be characterized as small ( $d = .2$ ), medium ( $d = .5$ ), or large ( $d = .8$ ). The partial  $\eta^2$  statistic, representing the proportion of variance accounted for, was calculated to estimate the magnitude of between-group differences in WIHIC and TOMRA scores after controlling for pretest, with partial  $\eta^2$  values considered modest (0.1), moderate (0.3), or strong (0.5) (Leech, et al., 2011; Richardson, 2011; Tolmie et al., 2011).

Second, in order to statistically control for differences in the pretest scores, MANCOVA was also conducted to investigate possible differences in 2:1 and 1:1 computing for the seven scales of the WIHIC when corresponding pretest scores were used as covariates. Then this was repeated for the three scales of the TOMRA. Because the multivariate test yielded statistically significant results in each case, individual ANCOVAs for each learning environment and attitude scale were also analyzed (Leech, et al., 2011).

Finally, means were compared in Figures 4.1 and 4.2 for both the 2:1 and 1:1 computing groups. Each individual scale of the WIHIC and TOMRA were also analyzed using these simple descriptive statistics.

The correlations between the students' scores on the WIHIC and TOMRA and WIHIC and NYSE were examined in response to Research Question 3. According to Tolmie et al. (2011), "Pearson's  $r$  is very commonly used in social research to look at the relationship between two variables, since it has the advantages of easy comparability with the correlations for ordinal variables, easy computation and ready interpretability" (p. 99). Although this correlational method, which is often used to conduct research in natural settings, can provide insight into complex relationships, it may identify small variations and produce statistically significant results that do not generalize (Anderson & Arsenault, 1998). In these situations, further research or additional sources of information are necessary to corroborate findings.

The Pearson correlation coefficient measures the magnitude and direction of linear relationships between variables (Grissom & Kim, 2011). The effect sizes measured by the

coefficients can be characterized as weak (less than +/- 0.1), modest (+/- 0.1-0.3), moderate (+/- 0.3-0.5), strong (+/- 0.5-0.8), or very strong (greater than +/- 0.8) (Tolmie et al., 2011).

#### **4.2.1 Differences between the Learning Environments for 1:1 and 2:1 Computing Classes**

Research Question 1: Are there differences in students' perceptions of their learning environments when studying in 1:1 or 2:1 computing environment?

In order to partly answer Research Question 1, concerning the effectiveness of 2:1 classes, 1:1 and 2:1 classes were compared in terms of students' perceptions on the seven WIHIC scales (Student Cohesiveness, Teacher Support, Involvement, Investigation, Task Orientation, Cooperation, and Equity) at the time of posttesting. However, because of the possibility that 1:1 and 2:1 classes might have been different in important ways at the time of pretesting, pretest WIHIC scores also were taken into account in these analyses in two ways.

First, as shown in Table 4.1, the 1:1 group with the 2:1 group were compared separately at pretesting and at posttesting using both significance tests and effect sizes. Initially, in order to reduce the Type 1 error rate, MANOVA was conducted with the seven WIHIC scales as the dependent variables. Because the multivariate test using Wilks' lambda criterion revealed statistically significant differences between 1:1 and 2:1 classes for set of WIHIC scales, the univariate ANOVA was interpreted separately for each individual WIHIC scale as shown in Table 4.1. In order to describe the magnitude of the difference between 1:1 and 2:1 classes for each WIHIC scale, Cohen's d was calculated (see Table 4.1).

Second, as noted above, 1:1 and 2:1 classes were compared in terms of WIHIC posttest scores while statistically controlling for pretest scores. MANCOVA was initially conducted for the set of seven WIHIC scales and, when this multivariate test yielded significant overall differences, the univariate ANCOVA was interpreted separately for each WIHIC scale as shown in Table 4.1. To estimate the magnitude of between-group differences in WIHIC scores after controlling for pretest, the partial  $\eta^2$  statistic was calculated and recorded in the last column of Table 4.1.

Table 4.1 shows that indeed there were differences in the learning environment of 1:1 and 2:1 classes at the time of pretesting and that these initial differences diminished by the time of posttesting:

- For Student Cohesion, and relative to the 1:1 group, scores for the 2:1 group were 0.18 SDs below at pretesting but 0.07 SDs above at posttesting.
- For Teacher Support, and relative to the 1:1 group, scores for the 2:1 group were 0.62 SDs below at pretesting and 0.05 SDs below at posttesting.
- For Involvement, and relative to the 1:1 group, scores for the 2:1 group were 0.42 SDs below at pretesting and 0.12 SDs below at posttesting.
- For Investigation, and relative to the 1:1 group, scores for the 2:1 group were 0.30 SDs below at pretesting but 0.30 SDs above at posttesting.
- For Task Orientation, and relative to the 1:1 group, scores for the 2:1 group were 0.29 SDs below at pretesting and 0.08 SDs below at posttesting.
- For Cooperation, and relative to the 1:1 group, scores for the 2:1 group were 0.30 SDs below at pretesting and 0.10 SDs below at posttesting.
- For Equity, and relative to the 1:1 group, scores for the 2:1 group were 0.34 SDs below at pretesting but 0.12 SDs above at posttesting.

ANOVA results in Table 4.1 show that, for Teacher Support and Involvement, significant differences in favor of the 1:1 group at pretesting disappeared by the time of posttesting. For Investigation, a significant difference in favor of the 1:1 group at pretesting became a significant difference in favor of the 2:1 group by the time of posttesting.

The ANCOVA results in Table 4.1 show that, after controlling for pretests, between-group differences at posttesting were statistically significant for Involvement and Investigation, with effect sizes (proportion of variance) of 0.04 and 0.07, respectively. That is, the 2:1 group perceived significantly higher classroom Involvement and Investigation than did the 1:1 group at the time of posttesting when pretest differences were controlled statistically. Despite the statistical significance, the partial  $\eta^2$  values indicate weak effects.

Table 4.1 Comparison of 1:1 (N = 35) and 2:1 (N = 89) computing environments on WIHIC scales at pretesting and posttesting

Scales		1:1		2:1		Difference F-value	Effect size d	ANCOV A	Result s
		computing environmen t		computing environmen t					
		Mean	SD	Mean	SD			F-value	Partial eta <sup>2</sup>
<i>WIHIC:</i>									
Student	Pre	4.39	0.52	4.30	0.50	0.79	0.18	2.81	0.02
Cohesion	Post	4.43	0.61	4.47	0.53	0.11	-0.07		
Teacher	Pre	3.95	0.81	3.56	0.68	7.40*	0.62	2.82	0.03
Support	Post	3.81	0.79	3.77	0.81	0.05	0.05		
Involvement	Pre	3.75	0.58	3.48	0.71	4.12*	0.42	4.13*	0.04
	Post	3.57	0.60	3.65	0.77	0.35	0.12		
Investigation	Pre	3.60	0.81	3.37	0.76	2.22*	0.30	8.91**	0.07
	Post	3.45	0.73	3.69	0.84	2.16*	-0.30		
Task	Pre	4.53	0.39	4.37	0.68	1.33	0.29	0.23	0.00
Orientation	Post	4.55	0.38	4.51	0.64	0.13	0.08		
Cooperation	Pre	4.26	0.49	4.08	0.68	1.77	0.30	0.57	0.01
	Post	4.14	0.71	4.07	0.66	0.26	0.10		
Equity	Pre	4.43	0.70	4.17	0.84	0.12	0.34	2.12	0.02
	Post	4.15	0.81	4.25	0.79	0.45	-0.12		

\*\*  $p \leq 0.01$

\*  $p \leq 0.05$

Consistent with the above summary of the findings from Table 4.1, Figure 4.1 provides a clustered column chart that compares the pre and post average item means of students studying in 2:1 and 1:1 computing classes for each learning environment scale. This chart highlights a pattern in which the scores of students in the 2:1 classes increase between pretest and posttest and the scores of students in the 1:1 classes decrease between pretest and posttest for four out of the seven WIHIC scales, namely, Teacher Support, Involvement, Investigation, and Equity. An individual comparison of the change in means for each scale of the WIHIC for 2:1 and 1:1 computing learning environments follows in Figures 4.2-4.8.

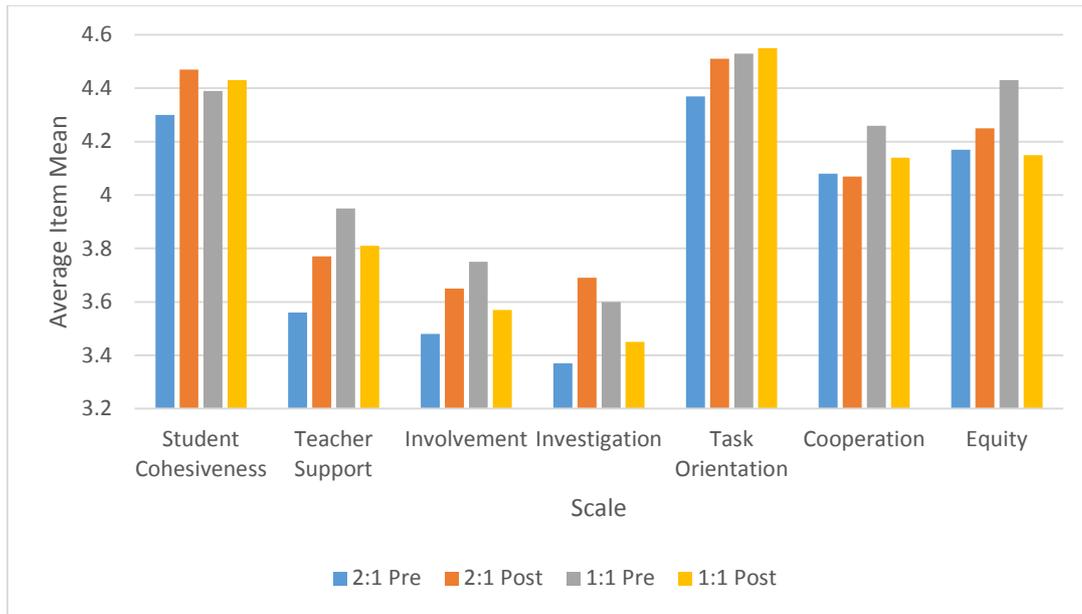


Figure 4.1 Comparison of Average Item Means on the WIHIC Scales 2:1 Computing and 1:1 Computing for Pretest and Posttest

***Student cohesiveness scale***

The means of the student responses to the student cohesiveness scale of the WIHIC increased between pretest and posttest from 4.30 to 4.47 (+0.17) for the 2:1 group and increased between pretest and posttest from 4.39 to 4.43 (+0.04) for the 1:1 group.

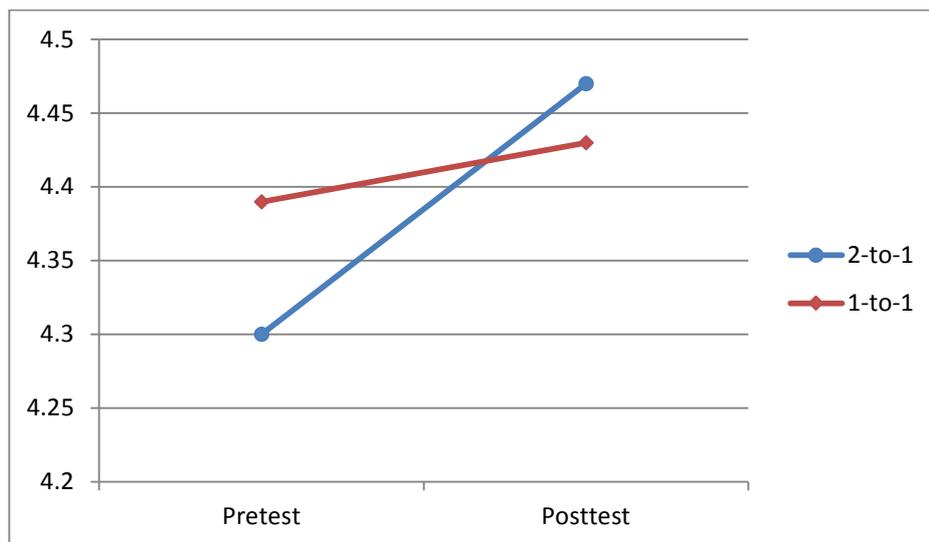


Figure 4.2 Comparison of Average Item Means on the Student Cohesiveness Scale 2:1 Computing and 1:1 Computing for Pretest and Posttest (ANCOVA  $F = 2.81$ , Not Significant)

### ***Teacher support***

The means of the student responses to the teacher support scale of the WIHIC increased between pretest and posttest from 3.56 to 3.77 (+0.21) for the 2:1 group and decreased between pretest and posttest from 3.95 to 3.81 (-0.14) for the 1:1 group.

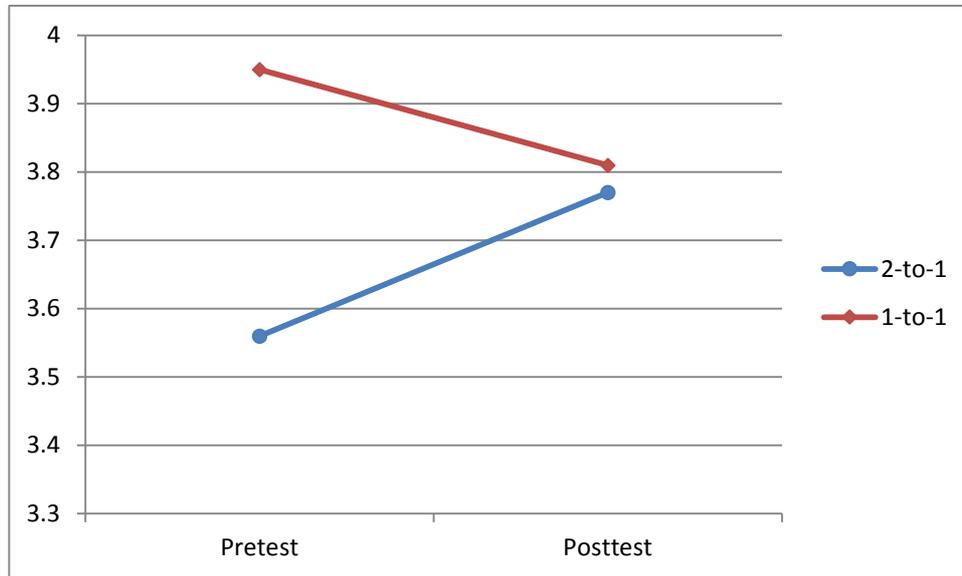


Figure 4.3 Comparison of Average Item Means on the Teacher Support Scale 2:1 Computing and 1:1 Computing for Pretest and Posttest (ANCOVA  $F = 2.82$ , Not Significant)

### ***Involvement***

The means of the student responses to the involvement scale of the WIHIC increased between pretest and posttest from 3.48 to 3.65 (+0.17) for the 2:1 group and decreased between pretest and posttest from 3.75 to 3.57 (-0.18) for the 1:1 group.

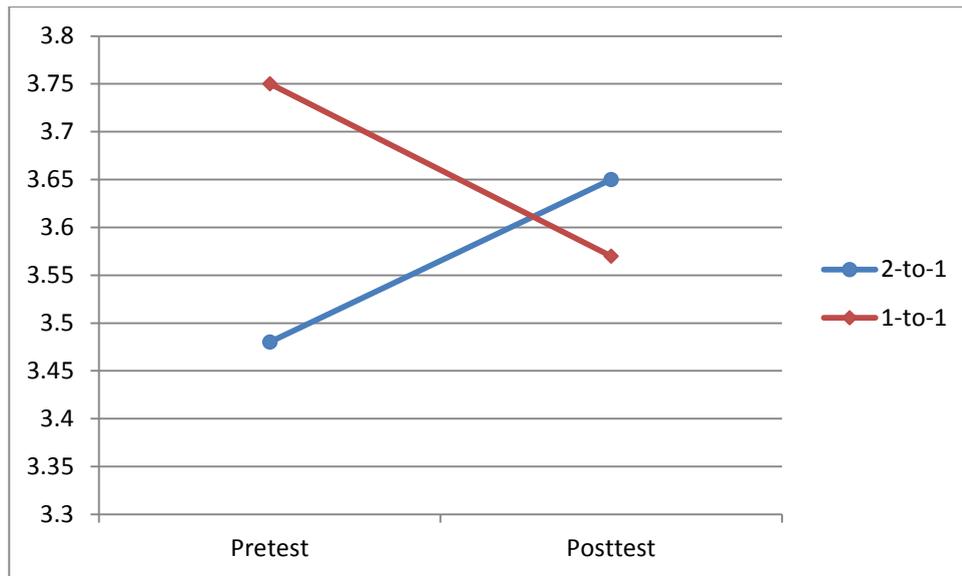


Figure 4.4 Comparison of Average Item Means on the Involvement Scale 2:1 Computing and 1:1 Computing for Pretest and Posttest (ANCOVA  $F = 4.13$ , Significant at  $p \leq 0.05$ )

### *Investigation*

The means of the student responses to the investigation scale of the WIHIC increased between pretest and posttest from 3.37 to 3.69 (+0.32) for the 2:1 group and decreased between pretest and posttest from 3.6 to 3.45 (-0.15) for the 1:1 group.

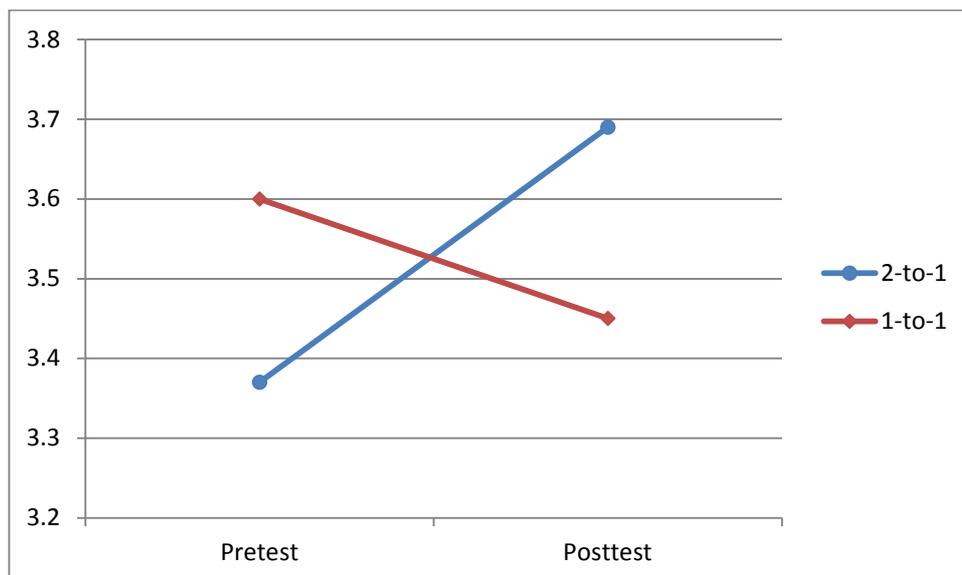


Figure 4.5 Comparison of Average Item Means on the Investigation Scale 2:1 Computing and 1:1 Computing for Pretest and Posttest (ANCOVA  $F = 8.91$ , Significant at  $p \leq 0.01$ )

### ***Task Orientation***

The means of the student responses to the task orientation scale of the WIHIC increased between pretest and posttest from 4.37 to 4.51 (+0.14) for the 2:1 group and increased between pretest and posttest from 4.53 to 4.55 (+0.02) for the 1:1 group.

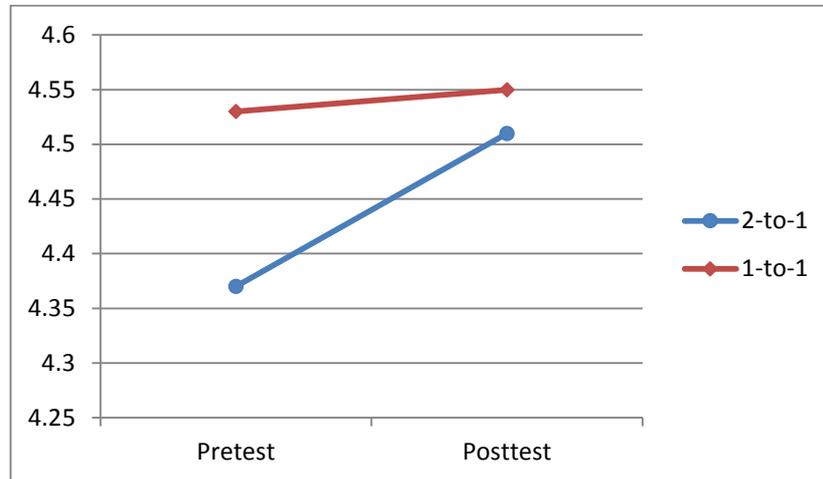


Figure 4.6 Comparison of Average Item Means on the Task Orientation Scale 2:1 Computing and 1:1 Computing for Pretest and Posttest (ANCOVA  $F = 0.23$ , Not Significant)

### ***Cooperation***

The means of the student responses to the cooperation scale of the WIHIC decreased between pretest and posttest from 4.08 to 4.07 (-0.01) for the 2:1 group and decreased between pretest and posttest from 4.26 to 4.14 (-0.12) for the 1:1 group.

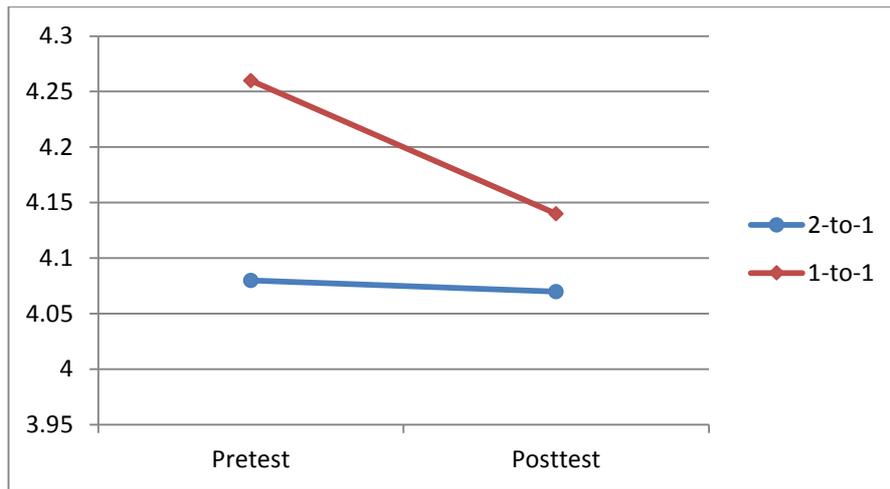


Figure 4.7 Comparison of Average Item Means on the Cooperation Scale 2:1 Computing and 1:1 Computing for Pretest and Posttest (ANCOVA  $F = 0.57$ , Not Significant)

### *Equity*

The means of the student responses to the equity scale of the WIHIC increased between pretest and posttest from 4.17 to 4.25 (+0.08) for the 2:1 group and decreased between pretest and posttest from 4.43 to 4.15 (-0.28) for the 1:1 group.

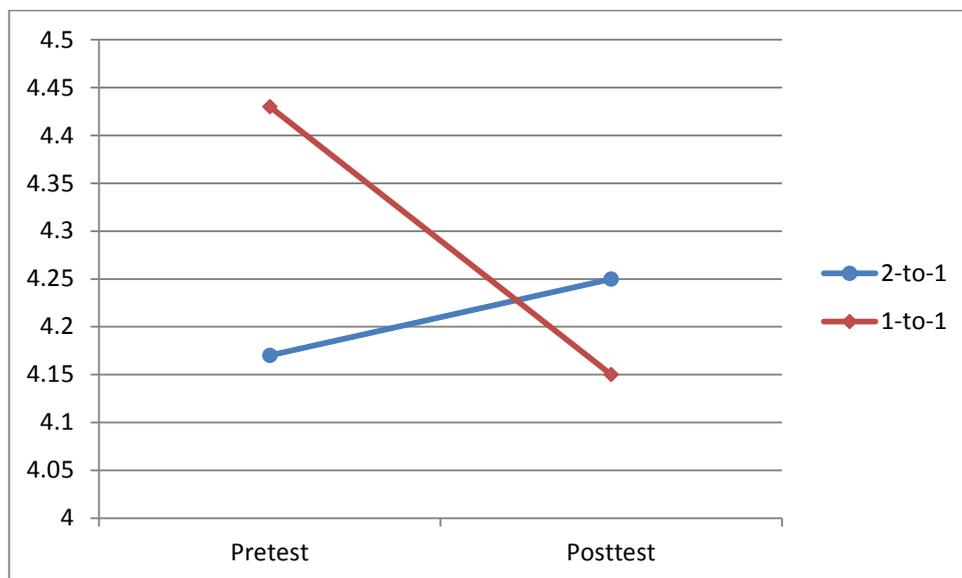


Figure 4.8 Comparison of Average Item Means on the Equity Scale 2:1 Computing and 1:1 Computing for Pretest and Posttest (ANCOVA  $F = 2.12$ , Not Significant)

#### **4.2.2 Differences between Students' Mathematics Attitudes for 1:1 and 2:1 Computing Classes**

Research Question 2: Are there differences in students' mathematics attitudes when studying in 1:1 or 2:1 computing environment?

In order to partly answer Research Question 2 concerning any discernable effectiveness of 2:1 classes, 1:1 and 2:1 classes were compared in terms of students' perceptions on the three TOMRA scales (Attitude towards Mathematics Inquiry, Adoption of Mathematics Attitudes, and Enjoyment of Mathematics Lessons) at the time of posttesting. However, because of the possibility that 1:1 and 2:1 classes might have been different in important ways at the time of pretesting, pretest TOMRA scores also were taken into account in these analyses in two ways.

First, as shown in Table 4.2, the 1:1 group with the 2:1 group were compared separately at pretesting and at posttesting using both significance tests and effect sizes. Initially, in order to reduce the Type 1 error rate, MANOVA was conducted with the three TOMRA scales as the dependent variables. Because the multivariate test using Wilks' lambda criterion revealed statistically significant differences between 1:1 and 2:1 classes for set of TOMRA scales, the univariate ANOVA was interpreted separately for each individual TOMRA scale as shown in Table 4.2. In order to describe the magnitude of the difference between 1:1 and 2:1 classes for each TOMRA scale, Cohen's *d* was calculated (see Table 4.2).

Table 4.2 Comparison of 1:1 (N = 35) and 2:1 (N = 89) computing environments on TOMRA scales in pretesting and posttesting

Scales		1:1 computing environment		2:1 computing environment		Differ- ence F-value	Effect size d	ANCOVA Results	
		Mean	SD	Mean	SD			F-value	Partial eta <sup>2</sup>
<i>TOMRA:</i>									
Attitude towards Mathematics Inquiry	Pre	2.26	0.63	2.46	0.51	3.28*	0.35	0.07	0.00
	Post	2.29	0.60	2.37	0.67	0.38	0.13		
Adoption of Mathematics Attitudes	Pre	2.20	0.44	2.28	0.44	1.00	0.18	0.56	0.01
	Post	2.23	0.42	2.24	0.50	0.06	0.02		
Enjoyment of Mathematics Lessons	Pre	2.39	0.84	2.33	0.89	0.12	0.07	0.41	0.00
	Post	2.61	0.80	2.52	0.98	0.19	0.10		

\*\*  $p \leq 0.01$       \*  $p \leq 0.05$

Second, 1:1 and 2:1 classes were compared in terms of the TOMRA posttest scores while statistically controlling for pretest scores. MANCOVA was initially conducted for the set of three TOMRA scales and, when this multivariate test yielded significant overall differences, the univariate ANCOVA was interpreted separately for each TOMRA scale as shown in Table 4.2. To estimate the magnitude of between-group differences in TOMRA scores after controlling for pretest, the partial eta<sup>2</sup> statistic was calculated and recorded in the last column of Table 4.2.

Table 4.2 shows that indeed there was a difference between 1:1 and 2:1 classes in the students' mathematics attitudes of 1:1 and 2:1 classes at the time of pretesting and that this initial difference diminished by the time of posttesting:

- For Attitude towards Mathematics Inquiry, and relative to the 1:1 group, scores for the 2:1 group were 0.35 SDs below at pretesting and 0.13 SDs below at posttesting.
- For Adoption of Mathematics Attitudes, and relative to the 1:1 group, scores for the 2:1 group were 0.18 SDs below at pretesting and 0.02 SDs below at posttesting.

- For Enjoyment of Mathematics Lessons, and relative to the 1:1 group, scores for the 2:1 group were 0.07 SDs below at pretesting and 0.10 SDs below at posttesting.

ANOVA results in Table 4.2 show that for Attitude towards Mathematics Inquiry significant differences in favor of the 1:1 group disappeared by the time of posttesting.

The ANCOVA results in Table 4.2 show that, when pretest differences were controlled statistically, posttest differences between 1:1 and 2:1 groups, were not statistically significant for any of the three scales of the TOMRA.

Figure 4.9 provides a clustered column chart that compares the pre- and post- average item means of students studying in 2:1 and 1:1 computing classes for each attitude scale. This chart highlights an interesting pattern in which the scores of students in the 2:1 classes decrease between pretest and posttest and the scores of students in the 1:1 classes increase between pretest and posttest for two out of the three TOMRA scales, namely, Attitude towards Mathematics Inquiry and Adoption of Mathematics Attitudes. Both the scores of students in the 2:1 and 1:1 classes trend increase between pretest and posttest for the TOMRA scale Enjoyment of Mathematics Lessons. An individual comparison of the pre-post change in means for each scale of the TOMRA for 2:1 and 1:1 computing learning environments follows in Figures 4.10-4.12.

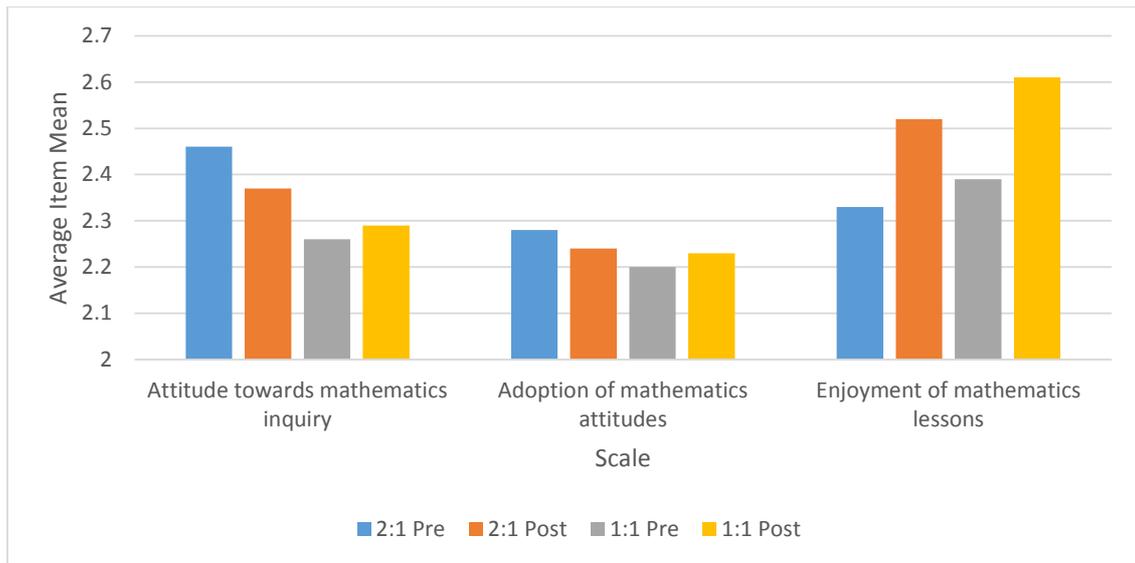


Figure 4.9 Comparison of Average Item Means on the TOMRA Scales 2:1 Computing and 1:1 Computing for Pretest and Posttest

***Attitude towards mathematics inquiry***

The means of the student responses to the attitude towards mathematical inquiry scale of the TOMRA decreased between pretest and posttest from 2.46 to 2.37 (-0.09) for the 2:1 group and increased between pretest and posttest from 2.26 to 2.29 (+0.03) for the 1:1 group.

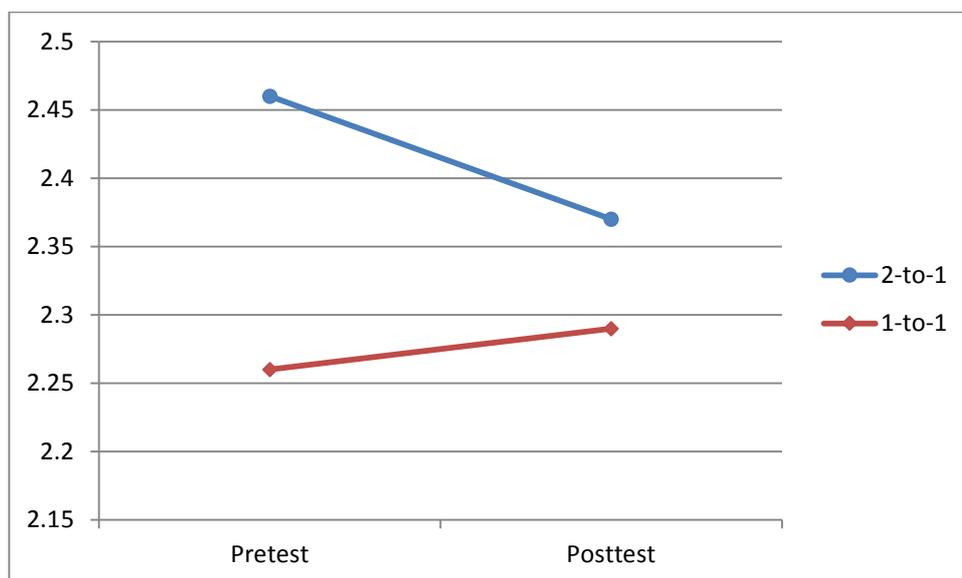


Figure 4.10 Comparison of Average Item Means on the Attitude towards Mathematics Inquiry Scale 2:1 Computing and 1:1 Computing for Pretest and Posttest (ANCOVA  $F = 0.07$ , Not Significant)

### *Adoption of mathematics attitudes*

The means of the student responses to the adoption of mathematics attitudes scale of the TOMRA decreased between pretest and posttest from 2.28 to 2.24 (-0.04) for the 2:1 group and increased between pretest and posttest from 2.20 to 2.23 (+0.03) for the 1:1 group.

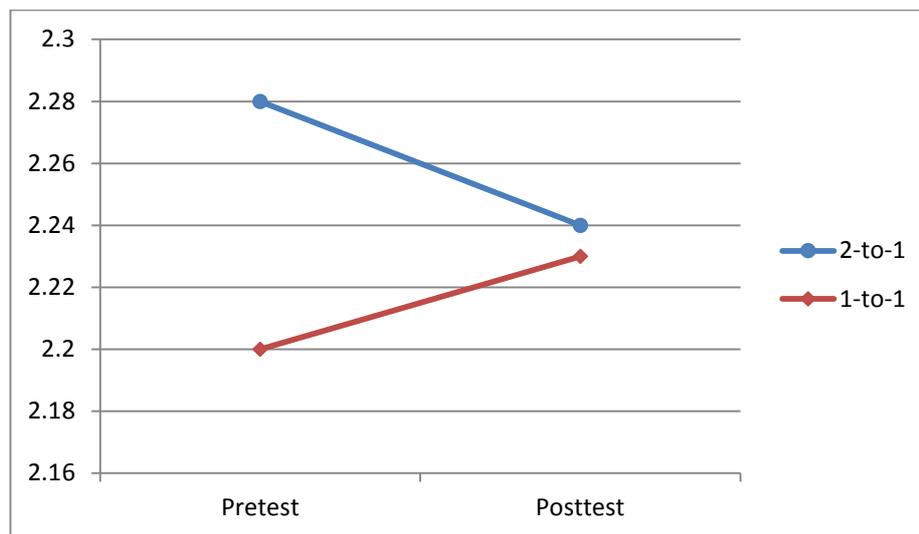


Figure 4.11 Comparison of Average Item Means on the Adoption of Mathematics Attitudes Scale 2:1 Computing and 1:1 Computing for Pretest and Posttest (ANCOVA  $F = 0.56$ , Not Significant)

### *Enjoyment of mathematics lessons*

The means of the student responses to the enjoyment of mathematics lessons scale of the TOMRA increased between pretest and posttest from 2.33 to 2.52 (+0.19) for the 2:1 group and increased between pretest and posttest from 2.39 to 2.61 (+0.22) for the 1:1 group.

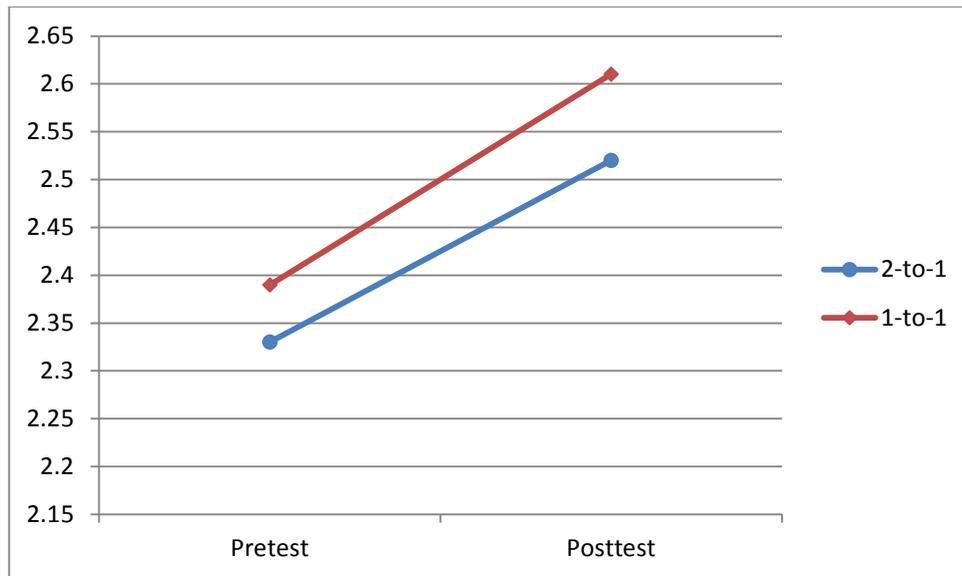


Figure 4.12 Comparison of Average Item Means on the Enjoyment of Mathematics Lessons Scale 2:1 Computing and 1:1 Computing for Pretest and Posttest (ANCOVA  $F = 0.41$ , Not Significant)

### 4.2.3 Correlations between the Learning Environment, Students' Mathematics Attitudes, and NYSE for 1:1 and 2:1 Computing Classes

Research Question 3: Are there statistically significant correlations between the learning environment scales, students' mathematics attitudes, and mathematics achievement when studying in 1:1 or 2:1 computing environment?

Table 4.3 presents the correlations between students' scores on the learning environment scales and mathematics attitudes scales and results from the mathematics achievement with NYSE when studying in 1:1 or 2:1 computing environment in order to answer Research Question 3.

While there is no overall consistent pattern of correlations, there were some statistically significant correlations between the WIHIC scales of Involvement and Investigation and the TOMRA scales of Attitudes towards Mathematics Inquiry and Adoption of Mathematics Attitudes.

In Table 4.3, the 1:1 correlations that were statistically significant are highlighted in yellow and 2:1 correlations that were statistically significant are highlighted in green.

Table 4.3 Correlations between WIHIC scales, TOMRA scales and NYSE achievement in 1:1 Computing (N = 35) and 2:1 Computing (N = 89)

WIHIC Scales	Computing Environment	Attitude towards Mathematics Inquiry	Adoption of Mathematics Attitudes	Enjoyment of Mathematics	NYSE
Student	1:1	0.34*	0.09	0.28*	0.50**
Cohesiveness	2:1	0.19	0.28**	0.27*	0.02
Teacher	1:1	0.04	0.16	0.47*	-0.05
Support	2:1	0.21	0.21	0.23*	-0.12
Involvement	1:1	0.13	0.16	0.45**	0.37**
	2:1	0.21*	0.32**	0.06	0.01
Investigation	1:1	0.36*	0.37*	0.38*	0.25
	2:1	0.31**	0.42**	0.20	0.06
Task	1:1	0.16	0.18	0.17	0.19
Orientation	2:1	0.30**	0.38**	0.26*	0.07
Cooperation	1:1	0.10	0.09	0.59**	0.18
	2:1	0.07	0.23*	0.05	0.01
Equity	1:1	0.27	0.18	0.52**	0.14
	2:1	0.07	0.11	0.15	-0.17

\*  $p < 0.05$  \*\*  $p < 0.01$

Looking at the 1:1 and 2:1 computer learning environments, in more detail, Attitude towards Mathematics Inquiry correlated with two WIHIC scales for 1:1 computing Student Cohesiveness (0.34) and Investigation (0.36). For 2:1 computing, Attitude towards Mathematics Inquiry was correlated with Involvement (0.21), Investigation (0.31), and Task Orientation (0.30). The correlations of Involvement and Task Orientation for 2:1 computing with Attitude towards Mathematics Inquiry are supported by the qualitative data in Section 4.3.

Adoption of Mathematics Attitudes correlated with most WIHIC scales for 2:1 computing while in 1:1 computing, only Investigation was significantly correlated. This result may warrant further investigation, since Adoption of Mathematics essentially did not change between pretest and posttest for 2:1 computing (-0.04) or 1:1 computing (+0.03).

Enjoyment of Mathematics correlated with most WIHIC scales for 1:1 computing while in 2:1 computing, correlations were only for Student Cohesiveness (0.27) Teacher Support (0.23) and Task Orientation (0.26). This difference may be due to the fact that Enjoyment of Mathematics (2.61) for 1:1 computing was the highest overall average item mean for the TOMRA scales implying that students enjoyed having their own computer.

The only statistically significant correlations between the WIHIC scales and the NYSE were for Student Cohesiveness and Involvement with the 1:1 computing learning environment. That there were no similar correlations for the same WIHIC scales with the 2:1 computing warrants further investigation because the class test means and standard deviations for the different computer environments were very similar as shown in Table 4.4.

*Table 4.4* Comparison of posttest-pretest mean differences of NYSE assessment results between 1:1 and 2:1 computing

Achievement test	2:1 computing (N = 89)		1:1 computing (N = 35)		t-value	Sig.
	Mean pre- post difference	SD	Mean pre- post difference	SD		
NYSE	-10.08	27.73	-16.00	25.98	1.07	0.29

### **4.3 Qualitative Data**

Danielson (2007, p. 21) states that “if the framework is used for mentoring or supervision, it ensures that teachers know what an observer is ‘looking for.’” The Lynbrook Public Schools Observation Form (see Appendix A) that is based upon the Danielson rubric, allowed the Lynbrook teachers to know exactly what was expected of them. The notes from the researcher and Director of Technology were collected during the observation process using the structure of the observation form. Some information was obtained through direct observation, and other notes were derived from conversations with students and staff members before, during, and after the lessons. This information was collected and is presented in such a way as to protect the interests of all parties involved and references to prior observations were not used in the data collection process for this reason as well.

Relevant qualitative data are included alongside the quantitative responses in order to supplement the answers to each of the research questions and triangulate the data.

#### **4.3.1 Differences between the Learning Environments of 1:1 and 2:1 Computing Classes**

Research Question 1: Are there differences in students’ perceptions of their learning environments when studying in 1:1 or 2:1 computing environment?

##### **Student Cohesiveness**

During the classroom observations in the 2:1 classes, the student groups seemed cohesive in that, for the majority of 2:1 classes observed, students worked well with their partners and shared their findings with the rest of the class. A student described the environment by saying, “We are all part of one big team in here, trying to discover the world of mathematics. We start with our partners and share what we find with the rest of the class so that we all become smarter.” The teachers concurred, and one offered, “I always seem to learn something new in class each day, and I have the students to thank for it. This is truly a learning community.”

In all 1:1 classes observed, individual activities allowing students to learn at their own pace were more dominant and sharing occurred after the inquiry or problem solving activities.

One student expressed this sentiment. “I really like that the computer helps me when I need it. Without its help, I could not complete my work and would need to wait for the teacher’s help.”

### **Teacher Support**

Teacher support in the 2:1 computing classes was evident, as teachers circulated throughout the classrooms offering the small groups support and focus, when necessary. The following quote summarizes the thoughts shared by several students. “Our teacher is an essential part of our group. Although the laptops are good, they do not teach us and help us when we are stuck.” In another class a student offered, “When we need her, our teacher magically appears and the math makes sense.”

During the observations conducted in the 1:1 computing classes, students spent more time working together and with the laptops than being directly instructed by teachers. Teachers assumed the roles of facilitators as students investigated mathematical concepts. There was a mix of different activities observed, and a student pointed out that “Sometimes we work in groups and other times we work alone. I prefer to work alone, but I know where to get help if I need it.” Although there was less direct instruction, this did not result in a decrease in teacher support. Teachers were able to circulate and offer specific support to those students, who in their perceptions needed the most help. One teacher commented, “I can focus on my students that need the most support and can differentiate my instruction using the data that the computer programs provide.” Although the teachers felt this way, a student shared the comment that “I do most of my work on my own and do not receive too much help from my teacher.” Similar opinions were also shared by other students.

### **Involvement**

During the classroom observations, mathematical discussions in each of the 2:1 computing classes were supported by information found on the laptop. Students took turns using the device and applied the information retrieved to the assigned problems and activities. When it was time for the students to report back to the classroom, the majority volunteered. One of the teachers described this phenomenon as a “natural outgrowth of the partner work.” Since the students practiced communicating mathematically with their partners, they claimed to feel

more confident when involved in whole class discussions. One student commented, “I feel more confident talking about math and participating in class since we started working together (in pairs) on the laptops.” This student also shared that he believed that this increased confidence positively affected his academic performance.

In the 1:1 computing classes, students were observed actively contributing to mathematical discussions and exploring mathematical information on their laptops. Teachers noted that they design their lessons to be student-centered in accordance with the Danielson Rubric. “Students are highly involved throughout the lessons using the laptops and I can monitor each student’s individual progress and adjust my lesson accordingly.” On the other hand, a student expressed that “Since I do most of my work on the computer, I do not participate in the class discussions.”

### **Investigation**

The students learning in the 2:1 computing classes supported the statistical significance of the increase in Investigation. One student emphasized the point that “All we do is investigate. We are math detectives.” In the majority of the classes observed, this was the case. Problems were posed and the laptops were used to help research and solve them.

Throughout the majority of lessons observed, students were investigating mathematical concepts during the lesson. Whether this was an individual or group activity varied from classroom to classroom; however, no matter what the format, the students were given an opportunity to construct their own knowledge. A student stated, “I teach myself the math. I can find out how to do anything on the computer,” while other students nodded in agreement.

### **Task Orientation**

In the 2:1 computing classroom observations, it was apparent that since students were responsible for each other’s success, students kept each other focused and oriented toward the tasks at hand. One student stated, “I am very focused during math class, and since I have a partner, I have no choice,” and his partner replied, “That is true, but we love solving math problems together, and we are good at it.” Other students also agreed with the concept of shared responsibility, and all those who spoke to the observers took pride in their joint work.

During the observations in the 1:1 computing classes, students appeared focused and this was apparent in the quality of their work. Teachers monitored their progress, and the students completed their assignments with little to no distractions and reported similar focus, when using laptops as part of their daily mathematics instruction. A student reflected, “Using the computer keeps me focused when I am learning math, much more so than when the teacher is talking.”

## **Cooperation**

Although the classroom observations showed that students were cooperative, overall, the computing environments did not seem to differ from the typical traditional classrooms in the level of cooperation. The teachers were in agreement with this observation, and one indicated “Students have always been generally cooperative in my classes and have worked hard to find their own successes.”

In the 1:1 classes, cooperation levels varied from class to class during the observations. Some classes had cooperation levels that compared to traditional mathematics classrooms, and others were more collaborative work environments. An insightful student pointed out that “When we work in groups, the computers allow all students to contribute to the discussion, even the weaker students. I think we should work in groups more.”

## **Equity**

Observations in the 2:1 classes demonstrated that students had equal opportunities to learn; however, none of the observations provided much insight into Equity. Conversations with students and teachers in the 2:1 classes were also limited in this area.

In the observations in the 1:1 computing classes, the majority of students had opportunities to work with their teacher individually or in a small group at some point during the lesson; however, not all students felt this way, as noted earlier. However, most agreed that they “get the help they need.”

### **4.3.2 Differences between Students' Mathematics Attitudes of 1:1 and 2:1 Computing Classes**

Research Question 2: Are there differences in students' mathematics attitudes when studying in 1:1 or 2:1 computing environment?

#### **Attitude toward Mathematics Inquiry**

Students observed using 2:1 laptops exhibited both positive and negative attitudes toward mathematics inquiry. One student reported that "I can discover ways to complete every assignment online, and I love learning new math." Unfortunately, the aforementioned student's partner admitted that "Since I work with a partner, I kind of follow her lead." These mixed perceptions were found in each of the 2:1 computing classes, but most students seemed more positive than not.

Students using 1:1 laptops showed a positive attitude towards mathematics inquiry during the observations. They worked diligently to find solutions to challenging word problems and attacked them from many angles. When they finally arrived at solutions, they were eager to show what they found out. A student remarked that "Using the computer allows me time to think of different ways to solve my math problems and present my answers to the class."

#### **Adoption of Mathematics Attitudes**

The adoption of mathematics attitudes was addressed only to a limited extent in the 2:1 classroom observations. A teacher in the 2:1 computing environment noted that students "bring fresh mathematical perspectives" to their discussions of mathematics. A student also shared a similar thought, "I like to discover mathematical ideas on the computer and make them my own."

In the 1:1 classes, the adoption of mathematics attitudes was not readily observable, nor was it well addressed by the students. Students showed interest in new ideas, but the teachers offered better insight. All teachers noted and one teacher articulated that "Students working with laptops are more inclined to tackle new challenges and work through multiple pathways in order to find a solution."

## **Enjoyment of Mathematics Lessons**

During the classroom observations, students' enjoyment of the mathematics lessons in the 2:1 computing classes was often expressed. For the most part, students worked well together and were motivated by and celebrated their successes. There were many testaments to this in each of the classrooms including the following student quotations: "Yes, we got the answer!" "I love this (activity)!", and "Can we do more math later?"

Similarly, students in the 1:1 classes enjoyed completing mathematics assignments using the laptops and spoke openly about it. One student exclaimed, "I love working with the laptops. I play games and learn math at the same time."

### **4.3.3 Correlations between the Learning Environment, Students' Mathematics Attitudes, and NYSE of 1:1 and 2:1 Computing Classes**

Research Question 3: Are there statistically significant correlations between the learning environment scales, students' mathematics attitudes, and mathematics achievement when studying in 1:1 or 2:1 computing environment?

First, the partner work and shared responsibility observed in the 2:1 computing classes supported the positive correlation between Task Orientation and the students' Attitudes towards Mathematics Inquiry, Adoption of Mathematics Attitudes, and Enjoyment of Mathematics. Students noted how their partners kept them focused on discovering mathematical concepts and problem solving. This focus encouraged students to continue exploring until solutions were found.

Second, the same focus on collaborative problem solving observed in the 2:1 computing environment may have contributed to the statistically significant correlations between Adoption of Mathematics Attitudes and 5 out of 7 scales of the WIHIC, namely, Student Cohesiveness, Involvement, Investigation, Task Orientation, and Cooperation.

Third, the excitement surrounding completing mathematical activities on one's own laptop observed in the 1:1 computing environment may have contributed to the statistically significant correlations between Enjoyment of Mathematics and 5 out of 7 scales of the

WIHIC, namely, Teacher Support, Involvement, Investigation, Cooperation, and Equity. Students were observed attempting new challenges and expressed that meeting those challenges was rewarding.

#### **4.4 Summary of the Chapter**

This chapter reported the findings of the study and attempted to address each of the three individual research questions. Since a mixed methodologies approach was employed during this study, both the quantitative results and qualitative information collected were presented.

To answer the first research question, the responses of the 89 fourth and fifth grade students in the 2:1 computing environment and 35 fifth grade students in the 1:1 computing environment were considered. It was found that the 2:1 group perceived significantly higher classroom Involvement and Investigation than did the 1:1 group at the time of posttesting when pretest differences were controlled statistically. These findings were supported by observations of mathematical investigation and problem solving with partners; in contrast, the students in the 1:1 group were more often seen working through problems and discovering mathematical concepts individually.

The answer to the second research question, based upon the responses of the 89 fourth and fifth grade students in the 2:1 computing environment and 35 fifth grade students in the 1:1 computing environment, was that the differences between 2:1 and 1:1 computing environments were not statistically significant for any of the three scales of the TOMRA, when pretest differences were controlled statistically. The similarities in the observational data collected in both 2:1 and 1:1 computing environments regarding student attitudes support the quantitative results.

The response to the third research question regarding correlations between learning environment and both attitude towards mathematics and achievement in the 1:1 computing environment was based upon the responses of the 89 fourth and fifth grade students in the 2:1 computing environment and 35 fifth grade students in the 1:1 computing environment. Although there was no overall consistent pattern of correlations, the data showed statistically significant correlations between the WIHIC scales and the TOMRA scales for both the 2:1 and 1:1 computing environments. This was consistent with Fraser's past research findings

that dimensions of the classroom environment were generally positively associated with student attitudes (Goh & Fraser, 2016). The particularly interesting results that may be worth further exploration were the statistically significant positive correlations for the 2:1 computing group between Task Orientation and the three scales of TOMRA, Attitudes towards Mathematics Inquiry, Adoption of Mathematics Attitudes, and Enjoyment of Mathematics, that were not statistically significant for the 1:1 computing group.

Overall, the 2:1 computing learning environment was found to have statistically significant positive effects in both the fourth and fifth grade mathematics classrooms in the areas of Involvement and Investigation, as compared to the 1:1 computing learning environment. There were no statistically significant differences between the 2:1 and 1:1 computing groups in terms of student attitudes towards mathematics based on the TOMRA. However, the positive correlations between the scales of the learning environment scales of the WIHIC and student attitude scales of the TOMRA can offer guidance for future study. This issue is discussed in Section 5.3.2.

## CHAPTER 5

### CONCLUSIONS, LIMITATIONS, AND IMPLICATIONS

#### 5.1 Introduction

The final chapter proposes conclusions, limitations, and implications of the study. Section 5.2 offers an overview of the thesis and a chapter by chapter summary. Next, Section 5.3 explains the limitations of the study, the significance of the study, and possible implications for future study. Finally, the chapter closes with a summary in Section 5.4.

The purpose of this study was to compare the impact of a 2:1 computing (one laptop per every two students) versus 1:1 computing (one laptop for every student) learning environment in fourth and fifth grade mathematics classrooms on factors such as student attitudes towards mathematics and achievement in mathematics. The study was conducted in Lynbrook, New York, United States of America, a small suburban community just outside of New York City. All of these students studied in traditional mathematics classrooms without laptop technology the year prior to the study and served as their own control groups.

The foci of this research study included:

1. Investigating whether or not there were differences in students' perceptions of their learning environments between the pretest and posttest for 2:1 computing compared to the difference between the pretest and posttest for 1:1 computing.
2. Investigating whether or not there were differences in student attitudes between the pretest and posttest when studying in the 2:1 computing environment compared to the difference between the pretest and posttest when studying in the 1:1 computing environment.
3. Investigating whether or not there were statistically significant correlations between the learning environment scales, students' attitudes towards mathematics, and achievement in mathematics when studying in 2:1 or 1:1 computing environment.

Other studies have shown benefits of introducing laptops and other computing devices in mathematics classrooms; however, the vast majority of them have been about 1:1 computing

models. This current research study focuses on a 2:1 computing model to see if there is similar impact on the learning environment as the 1:1 computing model in terms of student attitudes and achievement for upper elementary school mathematics students.

## **5.2 Overview of Thesis**

### **5.2.1 Summary of the First Chapter**

The first chapter offered an overview of the thesis and the rationale behind the study. As teaching and learning have evolved over the years, so has the instructional learning environment. One of the more recent developments has been the introduction of laptops and other technological initiatives, some of which have had better measured success than others.

As an administrator in a high performing school district, the researcher saw the need to gather reliable information to compare computing implementations in fourth and fifth grade mathematics classrooms. Expanding upon predecessors' works on 1:1 computing initiatives, the researcher developed a study to measure the differences in student attitudes and achievement of fourth and fifth grade students learning mathematics in 1:1 and 2:1 computing environments. Classroom environment instruments, students' scores on state assessments, and classroom observations formed the basis of the comparison.

Given the focus on mathematics and pressure associated with the No Child Left Behind Act of 2001, elementary mathematics instruction has taken center stage. Communities are discussing how mathematics is being taught and 21<sup>st</sup> century skills are being emphasized. Due to this movement, it is imperative that all changes to the learning environment be studied and measured. Since technology-enhanced learning environments do not bring about meaningful change in isolation, the roles of teachers, constructivism, problem solving, and small groups were also considered.

### **5.2.2 Summary of the Literature Review Chapter**

This chapter provided the basis for the research study, summarized prior research and offered background information regarding the programs and instruments used. In particular, the literature review supported the rationale for the following research questions: 1. Are there

differences in students' perceptions of their learning environments when studying in 1:1 or 2:1 computing environment? 2. Are there differences in students' mathematics attitudes when studying in 1:1 or 2:1 computing environment? 3. Are there statistically significant correlations between the learning environment scales, students' mathematics attitudes, and mathematics achievement when studying in 1:1 or 2:1 computing environments?

The chapter began with an examination of elementary mathematics learning environments, including constructivism, problem solving, and small group instruction. In such learning environments, students actively participate in the construction of their own knowledge and the process of solving meaningful problems, typically independently or in small groups, in order to fully understand and apply mathematical concepts. Teachers play an essential role in the learning process, collecting feedback from students, as they develop mathematical logic, and making adjustments as necessary.

Technology use in elementary classrooms was discussed, with a particular focus on how technology-enhanced, student-centered learning environments could support constructivism, problem solving, and small group instruction. The findings of various 1:1 computing initiatives offered characteristics and guidance for successful implementations and set the framework for both the 1:1 and 2:1 computing environments in this current research study. Planning, community vision and support, and integrated, pervasive use were recurring themes. In particular, there was a focus on the central role of the teacher and the need for ongoing, meaningful professional development. Additionally, the enVisionMATH program was presented as an available resource for the teachers included in this current study.

Students' attitudes toward elementary mathematics learning environments and the insight that they offer were shared. Features of the instruments used in this current research study to collect student attitudinal data, namely the WIHIC, TOMRA, and Danielson Framework for Teaching were presented.

Finally, the historical use of assessments to measure student achievement was discussed. Formative assessments were found useful to make adjustments as students learn new material, and summative measures were deemed to be the final standards by which students and schools are judged. The summative NYSE were examined from a historical perspective, and the test design, and flaws of the 2010 and 2011 NYSE used in this study to measure

achievement were also shared. Hope for the future of the NYSE was expressed, as dialogue for improvement in these curriculum measures continues.

### **5.2.3 Summary of Research Methods Chapter**

Chapter 3 described the research methodology used in this study, including research questions, research design, student sample, quantitative and qualitative data collection, triangulation, quantitative and qualitative analyses, and a summary. Quantitative and qualitative results were reported for each of the research questions to provide as much insight as possible. Overall, there were 124 student participants in the study; 35 students were instructed in a 1:1 computing environment and 89 students were instructed in a 2:1 computing environment. All of the students studied were fourth and fifth grade students attending elementary schools in the Lynbrook Union Free School District.

Multiple sources of data were collected during the study including: pretest-posttest student responses to the WIHIC (Aldridge et al., 1999) and TOMRA (Fraser, 1981), two years of the NYSE, and observational data. All scales of the WIHIC and TOMRA were administered to the students at the beginning of the intervention and again at the end of the school year. The NYSE were administered during the spring prior to the study and the spring during the study; therefore, the fourth grade students' data included the results from the third and fourth grade NYSE and the fifth grade students' data included the results from the fourth and fifth grade NYSE. On the qualitative side, data was collected using the Lynbrook UFSD Observation Form that is based upon the Danielson Framework for Teaching (Danielson, 2007). Both the researcher and Director of Technology conducted observations together and compared their notes. During the observation process, natural conversations occurred among the observers, the students, and the teachers. Relevant information was sorted by learning environment, 2:1 or 1:1 computing, and reported for each of the applicable research questions.

### **5.2.4 Summary of the Results Chapter**

#### **Differences between the Learning Environment of 1:1 and 2:1 Computing Classes**

When pretest differences were controlled statistically, it was found that the 2:1 computing classes had higher, statistically significant results on both the Involvement and Investigation

scales of the WIHIC compared to the 1:1 computing classes. In addition, it was found that the means for Teacher Support, Involvement, Investigation, and Equity scales of the WIHIC increased for the 2:1 computing classes and decreased for the 1:1 computing classes, despite the fact that the Teacher Support and Equity scales did not produce statistically significant differences in the posttests.

The qualitative data collected also supported these conclusions. In the 2:1 computing classes, teachers provided feedback to students to progress their learning, group and partner work were prevalent in most lessons and kept students involved, and lessons encouraged an investigative approach to problem solving. In the 1:1 computing classes, lessons tended to favor an individual, investigative approach to problem solving, and the teacher supported students who struggled.

### **Differences between Students' Mathematics Attitudes of 1:1 and 2:1 Computing Classes**

When pretest differences were controlled statistically, no statistically significant differences were found between the 1:1 and 2:1 computing classes on any of the three TOMRA scales measuring attitudes towards mathematics. Initially, at the time of pretesting the 1:1 classes had higher scores on each of the TOMRA scales as compared to the 2:1 computing classes, including a statistically significant difference for Attitude towards Mathematics Inquiry scale; by the time of the posttest, all of these differences diminished with the pretest differences controlled statistically. However, it was found that the means for Attitude towards Mathematics Inquiry and Adoption of Mathematics scales of the TOMRA increased for the 1:1 computing classes and decreased for the 2:1 computing classes, despite the fact that these scales did not produce statistically significant differences in the posttests. Whether or not these differences were based entirely on the pretest differences or were related to individual work, typical in the 1:1 computing classes, versus the partner work, typical in the 1:1 computing classes, could not be determined from the observational data. In general, the qualitative data did not reveal too many differences between the students' mathematics attitudes in the 1:1 and 2:1 computing classes. Students in both environments appeared to adopt positive attitudes towards mathematical thinking and inquiry, although some partners dominated in the 2:1 computing classes according to the students. As far as enjoyment of mathematics lessons, students in both 1:1 and 2:1 computing classes reported and were observed enjoying the lessons observed in support of the quantitative findings.

## **Correlations between the Learning Environment, Students' Mathematics Attitudes, and NYSE of 1:1 and 2:1 Computing Classes**

Although there was no overall consistent pattern of correlations, the data showed statistically significant correlations between the WIHIC scales and the TOMRA scales for both the 2:1 and 1:1 computing environments. The most consistent results were the statistically significant positive correlations for only the 2:1 computing group between Task Orientation and the three scales of TOMRA, Attitudes towards Mathematics Inquiry, Adoption of Mathematics Attitudes, and Enjoyment of Mathematics. In the 2:1 computing environment, students were typically observed working with partners developing mathematical concepts or problem solving. These students voiced their joint accountability and desire to successfully complete their work. This was not substantiated in this study, but it could be a subject for future work.

### **5.3 Limitations, Implications, and Significance of the Study**

This section describes the limitations of the study in Section 5.3.1 and the significance of the study and implications for future study in Section 5.3.2.

#### **5.3.1 Limitations of the Study**

The limitations to this study can be separated into two categories, those that were uncontrollable, namely: mortality threat, partial-sample bias, teacher differences and implementation fidelity, and the validity of the NYSE, and those that could be partially minimized, namely: selection bias, testing threat, the Hawthorne effect, and data collector characteristics and bias threats. Some of these limitations were inherent in the design of the study, others were introduced by the researcher's position in the district studied, and a final limitation became apparent after the study was underway.

#### **Design of the Study**

Two possible threats to internal validity, based upon the research design, were accounted for in this current research study. As noted in Section 3.3, the quasi-experimental research design introduced selection bias, since the student participants were not randomly selected. However, this is the usual situation in most small scale educational studies. To address this

situation, the non-equivalent groups were accounted for in the statistical analyses as covariates as described in section 4.2. The variances of the mean data attributed to the covariates were controlled so that the results were based upon effects of the independent variables only (Tolmie et al., 2011). The second threat to internal validity was a testing threat, meaning that students may have been aware of what was being studied based upon the pretest and altered their responses to the treatments (Cohen et al., 2011; Fraenkel & Wallen, 2006). This threat was mediated through the anonymity of the administration, taking away individual student's incentive to 'improve,' and the fact that the treatment was incorporated as part of normal instruction, not as a distinct experiment (Anderson & Arsenault, 1998; Fraenkel & Wallen, 2006).

In addition, the research design introduced a threat to external validity, known as the Hawthorne effect, caused by the novelty of the treatments and the possible increased recognition of the subjects (Clark, 1983; Fraenkel & Wallen, 2006; Hew & Brush, 2006). In order to help remedy this effect, both of the groups being compared received novel treatments, i.e., learning in either the 1:1 or 2:1 computing environment that had not been used in these classes previously (Fraenkel & Wallen, 2006).

### **Researcher's Role in the District**

Although working in the school district being studied offered familiarity with the learning environments and ease of access to the schools and the classes that may have not otherwise been granted, the researcher's role in the district did pose some challenges and introduce some limitations. As a district level supervisor, the researcher did not want the teachers to feel that the surveys would be used in any way to rate their teaching abilities. In order to limit the connection between the students completing the WIHIC and TOMRA and their classroom teachers, the surveys were administered by the teachers without the researcher present. Some of the teachers did not follow up when students did not complete and save the forms, which increased the effects of the mortality threat, as several students did not complete both surveys adding to the number of students who were not present to take both state mathematics assessments of the NYSE (Fraenkel & Wallen, 2006). Students with incomplete data sets were omitted from the study; consequently the number of participants was reduced and this introduced a partial-sample bias (Grissom & Kim, 2011). Although

potential data points were lost, a significant number remained to conduct the quantitative analyses.

As a result of the fact that the qualitative data collectors were limited to district administrators, the study was subject to both data collector characteristics and bias threats (Fraenkel & Wallen, 2006; Spinner & Fraser, 2005). The former threat was mediated by both observers remaining constant, collecting data together and analyzing it separately, and observing the 1:1 and 2:1 computing groups equally (Fraenkel & Wallen, 2006). The latter threat was present in the sense that the observers were not impartial, but that was the case in both the 1:1 and 2:1 computing environments. To minimize the effects of both of these threats, only quotes and conclusions included in both observers' analyses were included.

Although the classroom observations and conversations with students and staff were very insightful and mostly provided support of the quantitative findings, the researcher's position limited the way that they could be conducted. It was agreed upon before the research was conducted that specific student and teacher data would not be collected or reported. This meant that all information was tied to either the 2:1 or 1:1 computing environments not to specific classrooms. In other words, it was impossible to connect students' thoughts about the learning environment to those of their specific teachers, which may have been more insightful. Additionally, implementation fidelity is an inherent limitation of a technology effects approach, especially as it relates to the lack of control over key achievement-related variables in this study, and both teacher differences and implementation fidelity could not be properly accounted for (Bebell & Kay, 2010; Shapley et al., 2010; Suhr et al., 2010). These issues were unavoidable from the onset of the study, and inconsistent use of laptops in individual classrooms could have introduced differences in the impact of their effectiveness in altering the learning environments. However, as noted in Section 3.3.3, all participating teachers received the same staff development information and were subject to similar natural monitoring of lessons and lesson plans. Teachers not only learned about the same instructional practices and resources; they were also given time to co-plan lessons both during the professional development sessions and monthly grade level meetings, limiting the teacher differences to some extent for those who taught the 2:1 as compared to the 1:1 computing environment classes. In addition, all classes were naturally subject to the principals' bi-weekly monitoring of lesson plans, and at a minimum weekly, informal observations, grade level and data meetings to monitor teaching and learning in every

classroom, which offered some confidence in the implementation fidelity. Through comparing teachers' lessons to the established curricula and observing instruction frequently for short periods of time, the principals minimized differences in mathematics instruction across classrooms.

Finally, no research was conducted outside of the classroom setting; therefore, all conversations occurred naturally, as part of the observation process in order to be minimally disruptive to the normal lessons and not require students or teachers to miss instructional time. In other words, the school district's requirements did not allow for formal interviews or focus group discussions. Nevertheless, the students and teachers were very forthcoming with information in the natural setting as evidenced by their willingness to answer questions and the thoroughness of their responses. Others reported similar limitations to the scope of the qualitative components of their studies (Bebell & Kay, 2010; Spinner & Fraser, 2005).

## **NYSE**

As detailed in Section 1.6, the NYSE received harsh criticisms from educators and politicians alike. The validity of the assessments was questioned and the development of replacement examinations that better measure the New York State mathematics curriculum began shortly after their administration. Regardless, the only available common mathematics assessments for this study were those provided by the New York State Education Department. Since the students in the district were high performers (above the state averages, see Table 3.1) pre-intervention, a regression threat was present (Fraenkel & Wallen, 2006). In addition, due to the nature of the state assessments, the data collected was non-specific and subject to change at any time, that is, the exact topics covered and the scoring system are subject to annual changes. Winerip (2011, p. 4) quoted Dr. Tisch, the chancellor of the Board of Regents, at a June 2010 news conference as saying that "the state test scores are so ridiculously inflated that only a fool would take them seriously." He additionally reported that she said that state scores were "to be scaled down immediately." Winerip (2011) also noted that in November 2011 education commissioner John B. King acknowledged that mathematics education in the state of New York was moving in the wrong direction and asserted that the national set of standards of the mathematical standards, commonly known as the Common Core, would help. The Common Core State Standards Initiative (2014) that King referred to was an attempt by the governors and other state leaders to create a unified curriculum throughout the

United States to produce students who are college and career ready. These standards have caused much controversy, so much so that in August 2013, Ravitch (2013) blames King and Tisch for a ‘manufactured’ crisis created by manipulated cut scores that increased the number of correct responses needed to be considered proficient in order to further demonstrate the need for such standards. Recently in order to address continued concerns, Infante (2016) in her memo to district superintendents and other leaders throughout New York State discussed upcoming changes to the 2016 NYSE aimed to improve both the students’ testing experiences and the validity of the assessments.

Since the district being studied relied entirely on the NYSE as their only standardized measure of success, the achievement measurements must be questioned. Unfortunately, all of these aforementioned comments were made after the study had commenced, and obviously, any validity to the comments and subsequent changes would impact the ability to trust the information derived from these examinations. Administering a standardized, pinpointed test may have offered better insight, but it was deemed too disruptive to the educational process and could not be agreed upon by all participants.

### **5.3.2 Significance of the Study and Implications for Future Study**

Prior to this study being conducted, research regarding the implementation of laptops in elementary classrooms has been primarily focused on 1:1 computing environments. Although limited in size, this study has shown promise for the 2:1 computing environment in fourth and fifth grade mathematics classrooms, demonstrating statistically significant positive effects of the learning environment in the areas of Involvement and Investigation. In addition, the study demonstrated that there were no other statistically significant differences between the 2:1 and 1:1 computing environments, which means that the 2:1 computing environment offered similar benefits in terms of students’ perceptions of the learning environment and students’ mathematics attitudes. With the positive effects on students’ perceptions of Involvement and Investigation and no other statistically significant differences, 2:1 computing environments may produce more benefits than 1:1 computing environments and require half the number of devices. These results were consistent with previous findings that showed technological learning platforms support collaborative learning (Li & Ma, 2010; Salomon, 1998; Wu & Liu, 2015).

As noted in Section 1.2, 1:1 computing and 2:1 computing refer to the access level of the available technologies, not instructional practices (Bebell & O'Dwyer, 2010). This study was significant in the sense that it addresses an identified gap in the literature, namely 2:1 computing, and reaffirms prior results linking learning environments to students' attitudes (Goh & Fraser, 2016; Shadish, Cook, & Campbell, 2002). The qualitative data and simple correlations also offer 'tentative patterns' for future confirmation (Bebell & Kay, 2010; Goh & Fraser, 1998; Spinner & Fraser, 2005). In particular, the analyses revealed statistically significant positive correlations for only the 2:1 computing group between Task Orientation and the three scales of TOMRA, Attitudes towards Mathematics Inquiry, Adoption of Mathematics Attitudes, and Enjoyment of Mathematics. These positive results supported the recommendation of Russell et al. (2004) to focus on high access settings, such as the daily 2:1 model in this study, as opposed to their study of low access 2:1 and 4:1 classes, where laptops were only available every two or four weeks respectively.

Similar to prior studies of 1:1 computing initiatives, this technology study must be considered in the light of greater educational reforms, which in this case was the constructivist learning environment (Bebell & O'Dwyer, 2010; Shapley et al., 2010; Weston & Bain, 2010). The statistically significant findings in the areas of Involvement and Investigation in the 2:1 computing environment support the findings of prior research that found that technologies support a constructivist instructional approach (Gulek & Demirtas, 2005; Kang et al., 2007; Keppell et al., 2006). In a study conducted in New York, Lowther et al. (2003) found comparable results that technology-enhanced classes better supported student-centered teaching and independent inquiry than classes without the technologies. However, all of these studies note that teachers' beliefs and practices were essential in the integration of technology into the constructivist approach to teaching and learning (Chere-Masopha & Bennett, 2007; Garthwait & Weller, 2005; Hayes, 2007; Penuel, 2006; Raes et al., 2012; Tay et al., 2013; Towndrow & Vaish, 2009). Unfortunately, teacher level data was unavailable to the researcher, and this limitation is noted in Section 5.3.1.

Even though these results for a 2:1 computing learning environment are promising, the results of this study are not a definitive affirmation of the learning environment, rather they illustrate the potential of 2:1 computing based upon the fourth and fifth grade implementation in the Lynbrook Public Schools (Bebell & Kay, 2010). Future studies with larger sample sizes in several different school settings must be conducted to verify the effects of the

learning environment on students' attitudes and motivation in elementary mathematics classrooms. Studies of varying duration would allow the researchers to determine the efficacy of this learning environment over time and add to the generalizability of the results (Wang & Hannafin, 2005). This work is essential, as schools attempt to provide students with exemplary education in technology-enhanced learning environments. Additionally, future studies are needed to examine the relationship between the 2:1 computing environment and student achievement measured by valid, reliable and non-contested assessments. It is critical that such studies utilize assessments that remain steady over time and consistently measure the curriculum being taught.

#### **5.4 Summary of the Chapter**

The differences between 2:1 and 1:1 computing learning environments in fourth and fifth grade mathematics classrooms are reported throughout this chapter. Statistically significant differences were found between the two environments in favor of the 2:1 computing environment in the learning environment areas of Involvement and Investigation, when pretest differences are statistically controlled. No other statistically significant differences were found between the two environments for the other WIHIC scales or any of the TOMRA scales, when pretest differences are statistically controlled. These conclusions were based upon the 89 participants in the 2:1 computing classes and 35 participants in the 1:1 computing classes.

The aforementioned results, coupled with the fact that the 2:1 computing environment demonstrated students' perceptions of increases in Teacher Support, Involvement, Investigation, and Equity, when the 1:1 computing environment did not, warrant more investigation into 2:1 computing as an alternative learning environment. The correlation between Task Orientation and the three scales of TOMRA, Attitudes towards Mathematics Inquiry, Adoption of Mathematics Attitudes, and Enjoyment of Mathematics, is also a promising result, requiring further investigation.

While discussing upcoming advancements in mathematics instruction, Terrell (2015) included "improvements in classroom technology, the growth of 1-to-1 programs in schools, flipped classrooms, and efforts to better integrate formative assessments into daily instruction." This research study and others like it are necessary to evaluate the effectiveness of these evolving

technology-enhanced learning environments. More time and further research must be dedicated toward studying the 2:1 computing learning environment to determine how it can support the needs of communities seeking ‘self-organizing’ schools that differentiate mathematics instruction and produce significant, measurable results (Weston & Bain, 2010).

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## Appendix A

### Lynbrook UFSD observation form

#### Lynbrook Public Schools Observation Report

Teacher: \_\_\_\_\_  
 Observer: \_\_\_\_\_  
 Date of observation: \_\_\_\_\_  
 School Building: \_\_\_\_\_  
 Time/Period \_\_\_\_\_

☐ Tenured                      ☐ Non-tenured (1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> Year)  
 ☐ Announced                ☐ Unannounced  
 Student modifications: ☐ Available ☐ Not available  
 Class/Grade/Subject \_\_\_\_\_  
 Date of Post-Conference: \_\_\_\_\_

#### I. Summary of Lesson:

<b>II. Planning and Preparation</b>	<b>Satisfactory</b>	<b>Needs Improvement</b>	<b>Unsatisfactory</b>
1. Shows evidence of organization, planning and preparation supporting a clear objective			
2. Selects objectives and content appropriate to developmental and educational levels of the students			
3. Incorporates technology and other resources to support instruction			
4. Demonstrates knowledge of subject matter			
5. Shows evidence of collaboration, collegiality and professional development			

<b>III. Teaching and Instruction</b>	<b>Satisfactory</b>	<b>Needs Improvement</b>	<b>Unsatisfactory</b>
1. Communicates the goal of the lesson			
2. Provides a variety of activities and/or instructional strategies			
3. Engages students and sustains interest in the lesson			
4. Employs effective questioning which promotes understanding			
5. Evidence of teacher-student rapport			
6. Appropriate pacing			
7. Summary and closure to lesson			
8. Communicates clearly and correctly both orally and in writing			

<b>IV. Student Learning and Assessment</b>	<b>Satisfactory</b>	<b>Needs Improvement</b>	<b>Unsatisfactory</b>
1. Assesses students' understanding of lesson's objective(s)			
2. Provides students with feedback on performance			
3. Utilizes assessment information to guide instruction			

Teacher: \_\_\_\_\_

Observer: \_\_\_\_\_

Date: \_\_\_\_\_

<b>V. Classroom Environment</b>	<b>Satisfactory</b>	<b>Needs Improvement</b>	<b>Unsatisfactory</b>
1. Provides a safe, orderly, and productive learning environment which emphasizes the importance of content and expectations for learning and achievement			
2. Utilizes classroom management techniques to create an atmosphere of mutual respect, purpose and equity			
3. Encourages appropriate student behavior through positive reinforcement			
4. Organizes physical space for maximum safety and the efficient utilization of facilities			
5. Establishes effective classroom procedures for time management, smooth transitions, and timely completions of non-instructional tasks			
6. Classroom is visually inviting and reflects current student work and curriculum			

**Aspects of Teaching Performance That Contributed Most to Lesson Effectiveness**

**Aspects of Teaching Performance Where Improvement or Change Would Contribute to Greater Lesson Effectiveness – Implement the Following:**

**Reference to prior observations**

This lesson  was satisfactory  needs improvement  was unsatisfactory

---

**Teacher** **Date**

---

**Observer** **Date**

cc: File  
Principal, Director, Coordinator

## Appendix B

### TOMRA used

1. I would prefer to find out why something is true by doing a problem than by being told.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

2. I enjoy reading about things which disagree with my previous ideas.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

3. Mathematics lessons are fun.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

4. Doing problems is not as good as finding out information directly from teachers.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

5. I dislike doing similar problems to make sure that I am understanding the concept.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

6. I dislike math lessons.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

7. I would prefer to do problems than read about them.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

8. I am curious about the world in which we live.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

9. School should have more math lessons each week.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

10. I would rather agree with people than investigate a problem to find out for myself.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

11. Finding out about new things is unimportant.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

12. Math lessons bore me.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

13. I would prefer to do my own problems than have a teacher explain them.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

14. I like to listen to people whose opinions are different from mine.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

15. Mathematics is one of the most interesting school subjects.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

16. I would rather find out about things by asking an expert than working on my own.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

17. I find it boring to hear about new ideas.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

18. Math lessons are a waste of time.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

19. I would rather solve a problem by experimenting than be told the answer.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

20. In mathematics problems, I like to use new methods which I have not used before.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

21. I really enjoy going to mathematics lessons.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

22. It is better to ask the teacher the answer than to find out by trying a problem.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

23. I am unwilling to change my ideas when evidence shows that the ideas are poor.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

24. The material covered in math lessons is uninteresting.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

25. I would prefer to do a problem on a topic than to read about it in a textbook.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

26. In mathematics problems, I identify unexpected results as well as expected ones.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

27. I look forward to math lessons.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

28. It is better to be told mathematical facts than to find them out from problem solving.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

29. I dislike listening to other people's opinions.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

30. I would enjoy school more, if there were no math lessons.

- strongly agree
- agree
- not sure
- disagree
- strongly disagree

## Appendix C

### WIHIC used

1. I make friendships among students in this class.

- almost never
- seldom
- sometimes
- often
- almost always

2. I know other students in this class.

- almost never
- seldom
- sometimes
- often
- almost always

3. I am friendly to members of this class.

- almost never
- seldom
- sometimes
- often
- almost always

4. Members of the class are my friends.

- almost never
- seldom
- sometimes
- often
- almost always

5. I work well with other class members.

- almost never
- seldom
- sometimes
- often
- almost always

6. I help other class members who are having trouble with their work.

- almost never
- seldom
- sometimes
- often
- almost always

7. Students in this class like me.

- almost never
- seldom
- sometimes
- often
- almost always

8. In this class, I get help from other students.

- almost never
- seldom
- sometimes
- often
- almost always

9. The teacher takes a personal interest in me.

- almost never
- seldom
- sometimes
- often
- almost always

10. The teacher goes out of his/her way to help me.

- almost never
- seldom
- sometimes
- often
- almost always

11. The teacher considers my feelings.

- almost never
- seldom
- sometimes
- often
- almost always

12. The teacher helps me when I have trouble with the work.

- almost never
- seldom
- sometimes
- often
- almost always

13. The teacher talks with me.

- almost never
- seldom
- sometimes
- often
- almost always

14. The teacher is interested in my problems.

- almost never
- seldom
- sometimes
- often
- almost always

15. The teacher moves about the class to talk with me.

- almost never
- seldom
- sometimes
- often
- almost always

16. The teacher's questions help me to understand.

- almost never
- seldom
- sometimes
- often
- almost always

17. I discuss ideas in class.

- almost never
- seldom
- sometimes
- often
- almost always

18. I give my opinions during class discussions.

- almost never
- seldom
- sometimes
- often
- almost always

19. The teacher asks me questions.

- almost never
- seldom
- sometimes
- often
- almost always

20. My ideas and suggestions are used during classroom discussions.

- almost never
- seldom
- sometimes
- often
- almost always

21. I ask the teacher questions.

- almost never
- seldom
- sometimes
- often
- almost always

22. I explain my ideas to other students.

- almost never
- seldom
- sometimes
- often
- almost always

23. Students discuss with me how to go about solving problems.

- almost never
- seldom
- sometimes
- often
- almost always

24. I am asked to explain how I solve problems.

- almost never
- seldom
- sometimes
- often
- almost always

25. I carry out investigations to test my ideas.

- almost never
- seldom
- sometimes
- often
- almost always

26. I am asked to think about the evidence for statements.

- almost never
- seldom
- sometimes
- often
- almost always

27. I carry out investigations to answer questions coming from discussions.

- almost never
- seldom
- sometimes
- often
- almost always

28. I explain the meaning of statements, diagrams and graphs.

- almost never
- seldom
- sometimes
- often
- almost always

29. I carry out investigations to answer questions that puzzle me.

- almost never
- seldom
- sometimes
- often
- almost always

30. I carry out investigations to answer the teacher's questions.

- almost never
- seldom
- sometimes
- often
- almost always

31. I find out answers to questions by doing investigations.

- almost never
- seldom
- sometimes
- often
- almost always

32. I solve problems by using information obtained from my own investigations.

- almost never
- seldom
- sometimes
- often
- almost always

33. Getting a certain amount of work done is important to me.

- almost never
- seldom
- sometimes
- often
- almost always

34. I do as much as I set out to do.

- almost never
- seldom
- sometimes
- often
- almost always

35. I know the goals for this class.

- almost never
- seldom
- sometimes
- often
- almost always

36. I am ready to start this class on time.

- almost never
- seldom
- sometimes
- often
- almost always

37. I know what I am trying to accomplish in this class.

- almost never
- seldom
- sometimes
- often
- almost always

38. I pay attention during this class.

- almost never
- seldom
- sometimes
- often
- almost always

39. I try to understand the work in this class.

- almost never
- seldom
- sometimes
- often
- almost always

40. I know how much work I have to do.

- almost never
- seldom
- sometimes
- often
- almost always

41. I cooperate with other students when doing assignment work.

- almost never
- seldom
- sometimes
- often
- almost always

42. I share my books and resources with other students when doing assignments.

- almost never
- seldom
- sometimes
- often
- almost always

43. When I work in groups in this class, there is teamwork.

- almost never
- seldom
- sometimes
- often
- almost always

44. I work with other students on projects in this class.

- almost never
- seldom
- sometimes
- often
- almost always

45. I learn from other students in this class.

- almost never
- seldom
- sometimes
- often
- almost always

46. I work with other students in this class.

- almost never
- seldom
- sometimes
- often
- almost always

47. I cooperate with other students on class activities.

- almost never
- seldom
- sometimes
- often
- almost always

48. Students work with me to achieve class goals.

- almost never
- seldom
- sometimes
- often
- almost always

49. The teacher gives as much attention to my questions as to other students' questions.

- almost never
- seldom
- sometimes
- often
- almost always

50. I get the same amount of help from the teacher as do other students.

- almost never
- seldom
- sometimes
- often
- almost always

51. I have the same amount of say in this class as other students.

- almost never
- seldom
- sometimes
- often
- almost always

52. I am treated the same as other students in this class.

- almost never
- seldom
- sometimes
- often
- almost always

53. I receive the same amount of encouragement from the teacher as other students do.

- almost never
- seldom
- sometimes
- often
- almost always

54. I get the same opportunity to contribute to class discussions as other students.

- almost never
- seldom
- sometimes
- often
- almost always

55. My work receives as much praise as other students' work.

- almost never
- seldom
- sometimes
- often
- almost always

56. I get the same opportunity to answer questions as other students.

- almost never
- seldom
- sometimes
- often
- almost always

## Appendix D

### Permission to use TOMRA and WIHIC

From: Barry Fraser [B.Fraser@curtin.edu.au]  
Sent: Tuesday, June 01, 2010 12:12 AM  
To: Beleckas, Gerard  
Subject: RE: Dinner at TGI Friday on 17 June and Research Questions

Gerry

I would start with the original WIHIC as there is so much validity support for it. The SA version is one-off and probably not even in English.

TOMRA is a modified version of TOSRA for science. Again start with the original and do your own modifications.

You have my permission to modify and use TOSRA.

Best wishes

Barry

## Appendix E

### 2010 and 2011 New York State Mathematics Assessments

The original Pupil Evaluation Program in New York State was designed to measure student achievement in third, sixth, and ninth grades; scores were separated into stanines and the bottom three stanines, 23% of the students, were deemed to be ‘Below Minimum Competence’ (Swanson, 1998). By 2010, the examinations had evolved into third through eighth grade English language arts and mathematics assessments, designed by CTB/McGraw-Hill with accompanying technical reports.

According to the New York State Testing Program 2010: Mathematics, Grades 3–8 Technical Report and New York State Testing Program 2011: Mathematics, Grades 3–8 Technical Report (CTB/McGraw-Hill LLC, 2010a, p. 4; CTB/McGraw-Hill LLC, 2011, p. 4), “The Grades 3–8 Mathematics Tests are New York State Learning Standards-based criterion-referenced tests composed of multiple-choice (MC) and constructed-response (CR) items differentiated by maximum score point. MC items have a maximum score of 1, short response (SR) items have a maximum score of 2, and extended-response (ER) items have a maximum score of 3.” In May 2010, all NYSE were administered over a two-day period, except for students in grade 4, for whom the assessments were administered over a three day period. The only significant difference in the format of the NYSE in May 2011 was that all assessments were administered over a three-day period. The relevant parts of the 2010 and 2011 test configuration tables can be found in Appendix E.

The blueprint of the assessments (CTB/McGraw-Hill LLC, 2010a, p. 5-6) described how “The NYSTP Mathematics Tests assess students on the content and process strands of New York State Mathematics Learning Standard.” CTB/McGraw-Hill claimed that “As a result of the alignment to both process and content strands, the tests assess students’ conceptual understanding, procedural fluency, and problem-solving abilities, rather than solely assessing their knowledge of isolated skills and facts.” The content strands for each grade level included: Number Sense and Operations, Algebra, Geometry, Measurement, and Statistics and Probability; the exact breakdown for each grade level studied can be found in Appendix F. According to the Mathematics Core Curriculum MST Standard 3 Prekindergarten - Grade 12 revised March 2005, what students should know and be able to do within each strand was

as follows (New York State Education Department, 2005, pp. 5-6). The Number Sense and Operations Strand included: understanding numbers and number systems, understanding meanings of operations and procedures, and computing accurately and making reasonable estimates. The Algebra Strand included: analyzing algebraically a wide variety of problem solving situations, performing algebraic procedures accurately, and recognizing, using, and representing algebraically patterns, relations, and functions. The Geometry Strand included: analyzing characteristics and properties of geometric shapes, identifying and justify geometric relationships, applying transformations and symmetry to analyze problem solving situations, and applying coordinate geometry to analyze problem solving situations. The Measurement Strand included: determining what can be measured and how, using units to give meaning to measurements, understanding that all measurement contains error and being able to determine its significance, and developing strategies for estimating measurements. The Statistics and Probability Strand included: collecting, organizing, displaying, and analyzing data, making predictions that are based upon data analysis, and understanding and applying concepts of probability. How the score points were distributed was determined by CTB/McGraw-Hill LLC in conjunction with panels of New York State teachers prior to the development of test questions. Finally, the validity of the NYSE is discussed in Section 3.8.2.

## Appendix F

### 2010 NYSE configuration table

Grade	Day	Book	Number of Items				Allotted Time (minutes)	
			MC	SR	ER	Total	Testing	Prep
3	1	1	25	0	0	25	45	10
	2	2	0	4	2	6	40	10
	Totals			25	4	2	31	85
4	1	1	30	0	0	30	50	10
	2	2	0	7	2	9	50	10
	3	3	0	7	2	9	50	10
	Totals			30	14	4	48	150

### 2011 NYSE configuration table

Grade	Day	Book	Number of Items				Allotted Time (minutes)	
			MC	SR	ER	Total	Testing	Prep
4	1	1	45	0	0	45	70	10
	2	2	0	8	4	12	70	10
	Totals			45	8	4	57	140
5	1	1	41	0	0	41	60	10
	2	2	0	4	4	8	50	10
	Totals			41	4	4	49	110

## Appendix G

### Content strand breakdown for the 2010 NYSE

Grade	Total Points	Content Strand	Target Points	Selected Points	Target % of Test	Selected % of Test
3	39	Number Sense and Operations	19	19	48	49
		Algebra	5	4	13	10
		Geometry	5	5	13	13
		Measurement	5	4	13	10
		Statistics and Probability	5	7	13	18
4	70	Number Sense and Operations	32	35	45	50
		Algebra	10	11	14	16
		Geometry	8	8	12	11
		Measurement	12	10	17	14
		Statistics and Probability	8	6	12	9

**Content strand breakdown for the 2011 NYSE**

Grade	Total Points	Content Strand	Target Points	Selected Points	Target % of Test	Selected % of Test
4	73	Number Sense and Operations	33	34	45	46
		Algebra	10	9	14	12
		Geometry	9	10	12	14
		Measurement	12	10	17	14
		Statistics and Probability	9	10	12	14
5	61	Number Sense and Operations	24	20	39	33
		Algebra	7	9	11	15
		Geometry	15	15	25	24
		Measurement	9	11	14	18
		Statistics and Probability	7	6	11	10

## Appendix H



### **Curtin University of Technology Science and Mathematics Education Centre**

## **Participant Information Sheet**

Marion Street Elementary School  
Principal  
100 Marion Street  
Lynbrook, NY 11563

Dear Principal,

My name is Gerard Beleckas. In addition to serving as the Assistant Superintendent for Curriculum, Instruction and Assessment for the Lynbrook Union Free School District, I am currently completing a piece of research for my Doctor of Science Education at Curtin University of Technology.

### **Purpose of Research**

I am investigating the research topic: “An Assessment of the Attitudes, Motivation, and Achievement of Fourth and Fifth Grade Students Learning Mathematics in Two-to-One Computing Learning Environments.”

### **Your Role**

I am seeking your permission to conduct research by asking for your students to take part in short computer based surveys. Responses will be categorized and reported as aggregated statistical data, numbers and percentages only.

Additionally, I plan on looking at each participants’ New York State Mathematics Assessment Scores (1, 2, 3, or 4) to determine whether or not they increased, decreased, or remained the same. Again, codes will be used to protect anonymity and only aggregated statistical data, numbers and percentages only, for each of the three categories will be recorded.

Finally, I plan on conducting a series of observations in each of the participating classes throughout the year to compare the students’ attitudes, motivation, and achievement. Rest assured that none of the observations will contain any information that will make a student or teacher identifiable.

### **Consent to Participate**

The students and your school’s involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities.

When you have signed the consent form I will assume that you have agreed to participate and allow me to use the students' data in this research.

**Confidentiality**

The information provided will be kept separate from the students' personal details, and only myself and my supervisor will only have access to this. The classroom observations will not have your name or any other identifying information on it and in adherence to university policy, the classroom observations will be kept in a locked cabinet for at least five years, before a decision is made as to whether it should be destroyed.

**Further Information**

This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval Number SMEC-47-10). If you would like further information about the study, please feel free to contact me on 516-887-0255 or by email [gbeleckas@lynbrook.k12.ny.us](mailto:gbeleckas@lynbrook.k12.ny.us). Alternatively, you can contact my supervisor Dr. David Treagust on (+618) 9266 7924 or by email [DTreagust@curtin.edu.au](mailto:DTreagust@curtin.edu.au).

**Thank you very much for your involvement in this research.  
Your participation is greatly appreciated.**

## PRINCIPAL'S CONSENT FORM

---

- I understand the purpose and procedures of the study.
  - I have been provided with the participation information sheet.
  - I understand that the procedure itself may not benefit me.
  - I understand that my schools involvement is voluntary and I can withdraw at any time without problem.
  - I understand that no personal identifying information will be used in any published materials.
  - I understand that all information will be securely stored for at least 5 years before a decision is made as to whether it should be destroyed.
  - I have been given the opportunity to ask questions about this research.
  - I agree to allow students form my school to participate in the study outlined to me.
- 

Name: \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

## Appendix I



### **Curtin University of Technology Science and Mathematics Education Centre**

## **PARENT Information Sheet**

My name is Gerard Beleckas. In addition to serving as the Assistant Superintendent for Curriculum, Instruction and Assessment for the Lynbrook Union Free School District, I am currently completing a piece of research for my Doctor of Science Education at Curtin University of Technology.

### **Purpose of Research**

I am investigating the research topic: “An Assessment of the Attitudes, Motivation, and Achievement of Fourth and Fifth Grade Students Learning Mathematics in Two-to-One Computing Learning Environments.”

### **Your Role**

I will conduct research by asking for your child to take part in short computer based surveys. Your child’s teachers and principal have already been contacted and have agreed in principle to the project. Responses will be categorized and reported as aggregated statistical data, numbers and percentages only.

Additionally, I plan on looking at each participants’ New York State Mathematics Assessment Scores (1, 2, 3, or 4) to determine whether or not they increased, decreased, or remained the same. Again, codes will be used to protect anonymity and only aggregated statistical data, numbers and percentages only, for each of the three categories will be recorded.

Finally, I plan on conducting a series of observations in each of the participating classes throughout the year to compare the students’ attitudes, motivation, and achievement. Rest assured that none of the observations will contain any information that will make a student or teacher identifiable.

### **Consent to Participate**

Your child’s involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities. When you have signed the consent form I will assume that you have agreed to participate and allow me to use your data in this research.

### **Confidentiality**

The information you provide will be kept separate from your personal details, and only myself and my supervisor will only have access to this. The classroom observations will not have your name or any other identifying information on it and in adherence to university

policy, the classroom observations will be kept in a locked cabinet for at least five years, before a decision is made as to whether it should be destroyed.

**Further Information**

This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval Number SMEC-47-10). If you would like further information about the study, please feel free to contact me on 516-887-0255 or by email [gbeleckas@lynbrook.k12.ny.us](mailto:gbeleckas@lynbrook.k12.ny.us). Alternatively, you can contact my supervisor Dr. David Treagust on (+618) 9266 7924 or by email [DTreagust@curtin.edu.au](mailto:DTreagust@curtin.edu.au).

**Thank you very much for your involvement in this research.  
Your participation is greatly appreciated.**

**PARENT CONSENT FORM**

---

- I understand the purpose and procedures of the study.
  - I have been provided with the participation information sheet.
  - I understand that the procedure itself may not benefit my child.
  - I understand that my and my child's involvement is voluntary and I can withdraw at any time without problem.
  - I understand that no personal identifying information like my name and address will be used in any published materials.
  - I understand that all information will be securely stored for at least 5 years before a decision is made as to whether it should be destroyed.
  - I have been given the opportunity to ask questions about this research.
  - I agree to allow my child to participate in the study outlined to me.
- 

Name: \_\_\_\_\_

Student Name: \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

## Appendix J



### **Curtin University of Technology Science and Mathematics Education Centre**

## **STUDENT Information Sheet**

My name is Gerard Beleckas. In addition to serving as the Assistant Superintendent for Curriculum, Instruction and Assessment for the Lynbrook Union Free School District, I am currently completing a piece of research for my Doctor of Science Education at Curtin University of Technology.

### **Purpose of Research**

I am investigating the research topic: “An Assessment of the Attitudes, Motivation, and Achievement of Fourth and Fifth Grade Students Learning Mathematics in Two-to-One Computing Learning Environments.”

### **Your Role**

I will conduct research by asking for you to take part in short computer based surveys. Your teachers and principal have already been contacted and have agreed to the project. Responses will be categorized and reported as numbers and percentages only.

Additionally, I plan on looking at your New York State Mathematics Assessment Scores (1, 2, 3, or 4) to determine whether or not they increased, decreased, or remained the same. Only numbers and percentages for each of the three categories will be recorded.

Finally, I plan on conducting a series of observations in your classes throughout the year. None of the observations will contain any information that will identify you or your teacher.

### **Consent to Participate**

Your involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities. When you have signed the consent form I will assume that you have agreed to participate and allow me to use your data in this research.

### **Confidentiality**

The information you provide will be kept separate from your personal details, and only myself and my supervisor will only have access to this. The classroom observations will not have your name or any other identifying information on it and in adherence to university policy, the classroom observations will be kept in a locked cabinet for at least five years, before a decision is made as to whether it should be destroyed.

### **Further Information**

This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval Number SMEC-47-10). If you would like further information about the study, please feel free to contact me on 516-887-0255 or by email [gbeleckas@lynbrook.k12.ny.us](mailto:gbeleckas@lynbrook.k12.ny.us). Alternatively, you can contact my supervisor Dr. David Treagust on (+618) 9266 7924 or by email [DTreagust@curtin.edu.au](mailto:DTreagust@curtin.edu.au).

**Thank you very much for your involvement in this research.  
Your participation is greatly appreciated.**

## STUDENT CONSENT FORM

---

- I understand the purpose and procedures of the study.
  - I have been provided with the participation information sheet.
  - I understand that the procedure itself may not benefit me.
  - I understand that my involvement is voluntary and I can withdraw at any time without problem.
  - I understand that no personal identifying information like my name and address will be used in any published materials.
  - I understand that all information will be securely stored for at least 5 years before a decision is made as to whether it should be destroyed.
  - I have been given the opportunity to ask questions about this research.
  - I agree to participate in the study outlined to me.
- 

Name: \_\_\_\_\_

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

## Appendix K

### Danielson Framework for Teaching domains and components

<b>Domain 1 Planning and Preparation</b>	<b>Domain 2 The Classroom Environment</b>
<p><b>a. Demonstrating Knowledge of Content and Pedagogy</b>            Knowledge of Content and the Structure of the Discipline            Knowledge of Prerequisite Relationships            Knowledge of Content-Related Pedagogy</p> <p><b>b. Demonstrating Knowledge of Students</b>            Knowledge of Child and Adolescent Development            Knowledge of the Learning Process            Knowledge of Students' Skills, Knowledge, and Language Proficiency            Knowledge of Students' Interests and Cultural Heritage            Knowledge of Students' Special Needs</p> <p><b>c. Selecting Instructional Outcomes</b>            Value, Sequence, and Alignment            Clarity            Balance            Suitability for Diverse Learners</p> <p><b>d. Demonstrating Knowledge of Resources</b>            Resources for Classroom Use            Resources to Extend Content Knowledge and Pedagogy            Resources for Students</p> <p><b>e. Designing Coherent Instruction</b>            Learning Activities            Instructional Materials and Resources            Instructional Groups            Lesson and Unit Structure</p> <p><b>f. Designing Student Assessment</b>            Congruence with Instructional Outcomes            Criteria and Standards            Design of Formative Assessments</p>	<p><b>a. Creating an Environment of Respect and Rapport</b>            Teacher Interaction with Students            Student Interactions with One Another</p> <p><b>b. Establishing a Culture for Learning</b>            Importance of the Content            Expectations for Learning and Achievement            Student Pride in Work</p> <p><b>c. Managing Classroom Procedures</b>            Management of Instructional Groups            Management of Transitions            Management of Materials and Supplies            Performance of Non-Instructional Duties            Supervision of Volunteers and Paraprofessionals</p> <p><b>d. Managing Student Behavior</b>            Expectations            Monitoring of Student Behavior            Response to Student Misbehavior</p> <p><b>e. Organizing Physical Space</b>            Safety and Accessibility            Arrangement of Furniture and Use of Physical Resources</p>

<p style="text-align: center;"><b>Domain 3 Instruction</b></p>	<p style="text-align: center;"><b>Domain 4 Professional Responsibilities</b></p>
<p><b>a. Communicating with Students</b>            Expectations for Learning            Directions and Procedures            Explanations of Content            Use of Oral and Written Language</p> <p><b>b. Using Questioning and Discussion Techniques</b>            Quality of Questions            Discussion Techniques            Student Participation</p> <p><b>c. Engaging Students in Learning</b>            Activities and Assignments            Grouping of Students            Instructional Materials and Resources            Structure and Pacing</p> <p><b>d. Using Assessment in Instruction</b>            Assessment Criteria            Monitoring of Student Learning            Feedback to Students            Student Self-Assessment and Monitoring of Progress</p> <p><b>e. Demonstrating Flexibility and Responsiveness</b>            Lesson Adjustment            Response to Students            Persistence</p>	<p><b>a. Reflecting on Teaching</b>            Accuracy            Use in Future Teaching</p> <p><b>b. Maintaining Accurate Records</b>            Student Completion of Assignments            Student Progress in Learning            Non-instructional Records</p> <p><b>c. Communicating with Families</b>            Information About the Instructional Program            Information About Individual Students            Engagement of Families in the Instructional Program</p> <p><b>d. Participating in a Professional Community</b>            Relationships with Colleagues            Involvement in a Culture of Professional Inquiry            Service to the School            Participation in School and District Projects</p> <p><b>e. Growing and Developing Professionally</b>            Enhancement of Content Knowledge and Pedagogical Skill            Receptivity to Feedback from Colleagues            Service to the Profession</p> <p><b>f. Demonstrating Professionalism</b>            Integrity And Ethical Conduct            Service To Students            Advocacy            Decision Making</p>

## Appendix L

### Representative questions from the 2010 NYSE

Assessment Questions	Grade Level	Strand
1. There were 9 people fishing at a lake. Each person caught 6 fish. What was the total number of fish caught by the 9 people? A 15 B 48 C 54 D 62	3	Algebra
2. David multiplies 19 by 21 and gets 399. Which of these estimations could be used to check whether David's answer is reasonable? A $10 \times 20$ B $10 \times 30$ C $20 \times 20$ D $20 \times 30$	4	Algebra
3. Heidi records the batting averages of different players on a baseball team. Which list correctly shows the batting averages in order from least to greatest? A 0.353, 0.309, 0.179, 0.172 B 0.309, 0.353, 0.179, 0.172 C 0.179, 0.172, 0.309, 0.353 D 0.172, 0.179, 0.309, 0.353	5	Algebra
4. There were 9 people fishing at a lake. Each person caught 6 fish. What was the total number of fish caught by the 9 people? A 15 B 48 C 54 D 62	3	Geometry

5. There were 9 people fishing at a lake. 4                      Geometry  
Each person caught 6 fish. What was the  
total number of fish caught by the 9  
people?  
A 15  
B 48  
C 54  
D 62
6. There were 9 people fishing at a lake. 5                      Geometry  
Each person caught 6 fish. What was the  
total number of fish caught by the 9  
people?  
A 15  
B 48  
C 54  
D 62
7. There were 9 people fishing at a lake. 3                      Measurement  
Each person caught 6 fish. What was the  
total number of fish caught by the 9  
people?  
A 15  
B 48  
C 54  
D 62
8. There were 9 people fishing at a lake. 4                      Measurement  
Each person caught 6 fish. What was the  
total number of fish caught by the 9  
people?  
A 15  
B 48  
C 54  
D 62
9. There were 9 people fishing at a lake. 5                      Measurement  
Each person caught 6 fish. What was the  
total number of fish caught by the 9  
people?  
A 15  
B 48  
C 54  
D 62

- |   |   |                                  |
|---|---|----------------------------------|
| 10. There were 9 people fishing at a lake. Each person caught 6 fish. What was the total number of fish caught by the 9 people?<br>A 15<br>B 48<br>C 54<br>D 62 | 3 | Statistics<br>and<br>Probability |
| 11. There were 9 people fishing at a lake. Each person caught 6 fish. What was the total number of fish caught by the 9 people?<br>A 15<br>B 48<br>C 54<br>D 62 | 4 | Statistics<br>and<br>Probability |
| 12. There were 9 people fishing at a lake. Each person caught 6 fish. What was the total number of fish caught by the 9 people?<br>A 15<br>B 48<br>C 54<br>D 62 | 5 | Statistics<br>and<br>Probability |