A Case Study of a Blended Learning Environment with a Focus on Mastery that Greatly Impacted Mathematics Proficiency at Herbert Hoover Elementary School, Alaska

A Thesis presented by:
David L. Jones
The College of Professional Studies

In partial fulfillments of the requirements for the degree of Doctorate of Education

Dr. Chris Unger
Advisor

Northeastern University
Boston Massachusetts

December 2016
Abstract

The purpose of this case study is to analyze how two teachers used technology to increase student achievement in mathematics at Herbert Hoover Elementary School in rural, Alaska, significantly increasing student outcomes on the Alaska Standardized Based Assessments in mathematics. The case study reviews the qualitative data collected through interviews with the administrator, teachers, and student focus groups through the lens of the Mastery Learning Theory. The research question guiding the study is “How has the development of a blended learning classroom with a focus on Mastery Learning greatly impacted mathematics achievement in two elementary school classrooms, as perceived by the teachers using the program, the administrator, and students?” The literature review presents research on the use of technology to differentiate math instruction, increase student’s engagement in mathematics instruction, Mastery Learning and students’ achievement in math. The case study presents how the blended-learning approach impacted student learning, as discerned by the teachers, students, and administrator involved. The results suggest that a blended-learning approach to learning math can greatly increase student achievement over and beyond typical instructional strategies employed in schools today.

Keywords: technology in the classroom, technology as motivation, differentiation using technology, hybrid/blended learning, mastery learning
Acknowledgements

It is with my deepest appreciation that I acknowledge my advisor Dr. Chris Unger. His encouragement, patience, and guidance made this journey the greatest educational experience of my life. I would also like to thank Dr. Kelly Conn my second reader for valuable input on ways to improve my study and for the time and energy spent doing so. Additionally I would like to thank Dr. Priscilla Schulte for her willingness to serve as the third member of my committee.

Without the support of my wife Ingrid this educational accomplishment would have not been possible. To my sons Jacob and Luke who sacrificed many of hours of family time due to the fact that I had to spend much time studying. I thank you for your understanding and patience.

I would also like to thank my colleague Dr. Valerie Brooks for encouragement and constructive critique of my writing as we journeyed through the Northeastern program together. I would also like to thank the administrator, the 5th grade and 6th grade teacher as well as the students who were willing to participate and give of their time for this case study.
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Collection</td>
<td>53</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>54</td>
</tr>
<tr>
<td>Validity and Credibility</td>
<td>54</td>
</tr>
<tr>
<td>Protection of Human Subjects</td>
<td>55</td>
</tr>
<tr>
<td>Conclusion</td>
<td>56</td>
</tr>
<tr>
<td>Chapter IV: Research Findings</td>
<td>57</td>
</tr>
<tr>
<td>Administrator’s Perspective</td>
<td>57</td>
</tr>
<tr>
<td>Teacher Perspective – 6th Grade</td>
<td>62</td>
</tr>
<tr>
<td>Teacher Perspective – 5th Grade</td>
<td>70</td>
</tr>
<tr>
<td>Student Perspective</td>
<td>77</td>
</tr>
<tr>
<td>Chapter V: Discussion of Research Findings</td>
<td>83</td>
</tr>
<tr>
<td>Revisiting the Problem of Practice</td>
<td>83</td>
</tr>
<tr>
<td>Discussion of Major Findings</td>
<td>85</td>
</tr>
<tr>
<td>Discussion of the Findings in Relationship to Mastery Learning</td>
<td>89</td>
</tr>
<tr>
<td>Discussion of Findings in Relationship to Literature Review</td>
<td>93</td>
</tr>
<tr>
<td>Conclusion</td>
<td>102</td>
</tr>
<tr>
<td>Limitations</td>
<td>104</td>
</tr>
<tr>
<td>Significance and Possible Implications of Study</td>
<td>105</td>
</tr>
<tr>
<td>Future Studies</td>
<td>106</td>
</tr>
<tr>
<td>Personal Reflection</td>
<td>108</td>
</tr>
<tr>
<td>References</td>
<td>111</td>
</tr>
<tr>
<td>Appendices</td>
<td>119</td>
</tr>
<tr>
<td>Appendix A</td>
<td>119</td>
</tr>
</tbody>
</table>
Chapter I: Introduction

Problem of Practice

The current method of math instruction in public schools is not producing the results desired to assure that the United States remains economically competitive in the global market (Hess, 2010; Hanushek, Jamison, Jamison, & Woessmann, 2008; Chudgar and Luschei, 2009; Petersen, Lastro-Anadon, Hanushek, Woessmann, 2011). According to the National Center for Educational Statistics, the United States placed 24th in the mathematics ranking of the PISA test where, “23 had higher average scores than the United States, 29 had lower average scores, and 12 had average scores not measurably different from the U.S. average score” (Fleischman, Hopstock, Pelczar, & Shelley, p. 1). President Obama in his State of the Union Address January 2011 added, “The quality of our math and science education lags behind many other nations. America has fallen to ninth in the proportion of young people with a college degree” (Obama B. H., 2011). Hunt and Tierney (2006) emphasizes the importance of improving our education to be competitive with other countries due to the fact that, “At issue is whose standard of living will rise and whose will fall in a global economic environment that demands ever larger numbers of highly trained and educated workers” (p. 7). As argued by many, if US students do not keep pace academically with students from other countries they will be unable to find employment in a knowledge based global economy (Hunt and Tierney, 2006; Hess, 2010).

In a 2006 review of state standards nationwide, the Fordham Institute (Finn, Julian, & Petrilli, 2006) gave Alaska a “D” rating on its math standards compared to the National Council of Teachers of Mathematics (NCTM) standards. As of 2015, the Alaska math standards will correct this discrepancy and align the state standards with the NCTM standards. Alaskan students will have to increase their math abilities dramatically at the time the new standards
replace the old standards. By July 1, 2015 each school district in Alaska will have to identify at least two assessments with a maximum of four assessments to determine their students’ mathematics achievement as mandated by the Department of Education and Early Development (DEED) of Alaska. In addition, the student outcomes of these assessments will be counted toward twenty percent or more of the teacher evaluations. This is an accountability measure by the state to make sure all students are getting adequate instruction.

The math curriculum that is used by most school districts today is designed to teach in a whole class method where students progress together page by page through the textbook adopted by the school district to teach mathematics. This method would be effective if all children had the same learning style and had matching aptitudes in mathematics. This is contradictory to the current understanding of developmental psychology where it is believed that specific capabilities will be unique to the individual based on genetic inheritance and life experience (McCown, Driscoll, & Roop, 1996). “Acknowledging that students learn at different speeds and they differ widely in their ability to think abstractly or understand complex ideas is like acknowledging that students of any given age are not all the same height” (Tomlinson, 2001, p. viii). American teachers will have to change from teacher-centered instructional methods to student-centered instructional methods and be able to differentiate their instruction accordingly if they want their students to be successful on standardized tests.

Current traditional math curriculum and instruction do not take into account that the individual student cannot move forward until he or she has mastered the skills needed for the next objective. For example, if a student does not know his multiplication facts you cannot move him on to a lesson teaching the student how to divide. When teachers move the students to the next lesson without prior mastery of the current lesson because of time constraints they set the
student up for failure. “Common experience, as well as abundant research evidence, suggests that the amount of time needed by the children even under … ideal conditions will differ widely” (Carroll, 1963). Students must be allowed the time to master prior skills before moving on to the lessons with a focus on later skills. Mastery learning is not a new concept. Benjamin S. Bloom (1974) saw inferences to mastery learning in the writings of Comenius, Pestalozzi, and Herbart. Bloom (1974) “reasoned that if we could provide the time and help needed and could motivate the student to use the time available, most students could be brought to the criterion level of achievement” (p. 684). Most standardized tests in the United States are criterion-based tests to meet the requirements of the Elementary and Secondary Education Act (NCLB).

Traditional classroom instruction focused on adherence to a textbook is a flawed concept in many aspects (Bloom, 1968; Dzakiria, Mustafa, & Bakar, 2006). The textbook is designed for students to be exposed to the concepts that the author of the textbook determines to be the appropriate material needed for each grade level. The content material is usually not taught to mastery level for all students (Block, 1971). Additionally, there is rarely a perfect alignment with the criteria of the standardized tests that students will be taking and the adopted textbooks of the traditional classroom. Perspicuous defined objectives with small formative assessments based on the standards to be tested must be designed, in place, and mastered so students can become successful on summative assessments (standardized tests) (Bloom, Hasting, Madaus, 1971).

**Significance of the Problem**

The Congressional Budget Office (CBO) in their January 2011 economic outlook forecast noted that there is “a mismatch between the requirements of existing job openings and the characteristics of job seekers” (Whalen, Kowalewski, & Arnold p. 27). This mismatch has
occurred because American public schools are still teaching students with the methods and to the academic level that was used when the United States economy was based on manufacturing. This shift from an economy driven by agriculture and industry to an economy that requires better-educated citizens will require dramatic change from public schools. As Hess (2006) states, “Our nation’s postindustrial and increasingly global economy is now driven by knowledge and by higher-order skills like symbolic reasoning, analysis, and communication” (p. 26). If the students in the United States do not keep pace academically with students from other countries they will be unable to find employment in a knowledge based global economy (Wagner, 2010).

If schools do not make the transition from industrial age methods of instruction to twenty-first instructional methods it will be difficult for the future generation to maintain the living standard that their parents enjoy. Chris Dede, who is the Timothy E. Wirth Professor in Learning Technologies at Harvard’s Graduate School of Education, asserted that the school classroom will not go away due to online learning, but will use the online technology to customize education for the individual student. As Dede (2007) wrote, “At this point in history, the primary barriers to altering curricular, pedagogical, and assessment practices toward the transformative vision of [information and communication technologies] ICT in education … are not conceptual, technical, or economic, but instead psychological, political, and cultural” (p. 35).

The need for change in educational pedagogy is due to the fact that the skill brought by students coming to public schools have changed and the skills they need to acquire for becoming productive members of society have altered as well (Edgar 2012; Papert, 1993; Kort & Reilly 2002, Dede, 2007). At Houghtaling School in Alaska, not unlike most communities across the US, the students coming into kindergarten begin with a wide range of capabilities in preparedness to begin their education in academic abilities as well as social skills to become
successful students. With the new technology of online learning, teachers can move past the current problems of practice and begin to implement the teachings of John Dewey and Lev Vygotsky with a focus on the educational needs of the individual student as their main focus of instruction moving from teacher centered to student centered instruction. Interactive software can be used as the “knowledgeable other” that Vygotsky believed was needed to construct knowledge. Dewey believed in a child center education that addressed the needs of the student that the technology makes possible with differentiation of lessons designed for the individual student (Gallant, 1973).

Instruction that is differentiated down to the individual student would not be possible for a single teacher in a typical classroom in the United States until recent technological advances. In 2009 61.9% of the non-disabled students of the 6th grade class at Herbert Hoover Elementary School were proficient in math on the Alaska Standards Based Assessment (SBA) test. This was increased to 93.2% proficient of the non-disabled student by the 2013 SBA math test by using various web-based tools and resources (the method used in this case study) to align student instruction to the individual student need. It is argued that the efficiency of an instructional method that can individualize math instruction in the elementary classroom by way of web-based programs and resources can produce a significant improvement in student outcomes.

In a collaboration between the New Media Consortium (NWC), the Consortium for School Networking (CoSN) and the International Society for Technology in Education (ISTE) the NMC Horizon Report: 2013 K-12 Edition (Johnson et al., 2013) stated, “Traditional lectures and subsequent testing are still dominant learning vehicles in schools” (p.10) and that schools needed to address blended learning and the growing success of non-traditional models of schooling. Additionally stated in the NWC Report: 2013 K-12 Edition (Johnson et al., 2013)
was their view that, “The demand for personalized learning is not adequately supported by current technology or practices” (p. 10). The report goes on to say that we are not using technology formative assessment to drive assessment in the way it could and should in the classroom (Johnson et al. 2013). Technology and in education has not been researched extensively and technology has not been implemented to its full potential in the world of education to benefit the individual student (Hess, 2006; Johnson et al, 2013; Staker & Horn, 2014).

**Positionality Statement**

In reflecting on my positionality of this case study I first acknowledge my background and how at the age of 45 entered the field of education. I am a Caucasian male, Christian, earning a middle class income. I was raised by my father, an internationally acclaimed research scientist in the field of industrial hygiene and my mother an administrator of nursing homes. I spent the majority of my life as a professional musician. In 2000 I became a music teacher and was hired under an emergency certificate to teach music. I was hired under an emergency certificate because I did not have a college degree or teaching certificate. My private studies in music began at age 7 and continued until I was 35 ending when I went to Alaska where there were not suitable music instructors in Southeast Alaska.

In 2002 I earned a Bachelor of Liberal Arts in General Studies after already teaching for two years. I continued my education earning Master in the Art of Teaching in 2005 and a Master in Education in Educational Leadership in 2007. In 2010 I entered Northeastern University to begin work on a doctorate of education. Four years after teaching music I was transferred to a classroom position due to the fact the school I was teaching at was closed. The second year of being a classroom teacher, in 2005, I was transferred to the school that this case study is situated
in. When I examined my 2005 class’s academic ability I came to the conclusion that the traditional method of math instruction would not bring about the outcomes that were needed for these students to become successful. I purchased eight Dell computers and began an individualized method of instruction. In 2013, I became the administrator of the site of this case study. A fifth grade teacher and a sixth grade teacher are still using the methods that were developed in 2005 who will be interviewed in this case study. “Inquirers explicitly identify reflexively their biases, values, and personal background such as gender, history, culture, and socioeconomic status, that may shape their interpretation formed during a study” (Creswell, 2007, p. 177). Bourke (2008) described positionality as the ability to reflectively self scrutinize with self-conscious awareness of the relationship between the researcher and the study. My inquiry is based on the statistically significant differences in outcomes between the classes involved in this case study and the rest of the similar grade classes outcomes examined school district wide. Alaska currently is without a state test so these classrooms are now compared to Measure of Academic Progress from Northwest Evaluation Association that will compare their growth internationally.

**Practical Goals**

The practical goal of this case study is to examine how the use of web-based programs and resources to differentiate instruction in the Herbert Hoover Elementary School might have contributed to an increase in Alaska Standards Based Assessment (SBA) math scores. Through this examination a curriculum can be designed that takes into account the differences of student cognitive development, the time needed to master desired skills and objectives, and clearly define objectives based on the standards to be tested. This will be examined by conducting
interviews with the administrator, the teachers, and focus groups of students involved with the innovation in instruction.

**Intellectual Goals**

There are two intellectual goals for this study:

1. To investigate how the instructors of this new design perceive the design is having a significant impact on student learning, mastery, and engagement.

2. To identify how different methods of math instruction might have contributed to an increase in the standardized test scores at Herbert Hoover Elementary School as perceived by teachers, administrators and students.

**Research Question**

The research question guiding this study is as follows:

How has the development of a blended learning classroom with a focus on mastery learning contributed to mathematics achievement in an elementary school, as perceived by three teachers using the program, the administrator, and students?

**Theoretical Framework: Mastery Learning Theory**

Mastery Learning theory with the use of blended learning will be used to examine how the use of web-based resources played a role in the increase of engagement and mathematical achievement and in this rural elementary school. Mastery learning is not a new concept. Benjamin S. Bloom wrote that the basic concepts of mastery learning date back as far as the teachings of Plato and Socrates (Guskey, 1997). Bloom (1974) states that varying forms of mastery learning appear in the methods of “Comenius in the seventeenth century, Pestalozzi in the eighteenth century, and Herbart in the nineteenth century” (p. 4). In the early twentieth century the work of Carleton Washburne and associates in the Winnetka Plan in 1922 and Henry
C. Morrison at the University of Chicago’s Laboratory School in 1926 implemented a method of mastery learning (Block, 1971). The implementation of mastery learning was successful at the University of Chicago’s Laboratory School, however, “the idea of mastery learning disappeared due primarily to the lack of technology required to sustain a successful strategy” (Block, 1971, p. 4). In the modern era Bloom’s 1968 paper *Learning for Mastery* is considered to be the current standard for the theoretical formulation on Mastery Learning (Guskey, 1997, Kulik, Kulik, & Bangert-Drowns, 1990).

Bloom’s basis for Mastery Learning was derived from the work of John B. Carroll’s (1963) “Model of School Learning” that claimed a majority of students can reach success in learning in school given the time and instruction needed. Carroll (1963) states that the time needed to master a learning objective would vary greatly among any group of students. James H. Block (1971) summarized this method as:

\[
\text{Degree of Learning} = f(1. \text{Time Allowed} \quad 2. \text{Perseverance} \\
3. \text{Aptitude} \quad 4. \text{Quality of Instruction} \\
5. \text{Ability to Understand Instruction})
\]

Bloom (1968) stated, “a learning strategy for mastery may be derived from the work of Carroll (1963)” (p. 3). Bloom (1968) addresses each of the five parts of Carroll’s formula for learning in his article, *Learning for Mastery*, published by the Center for the Study of Evaluation of Instructional Programs (CSEIP) located at the University of California Los Angeles which was sponsored by the United States Office of Education.

Bloom (1968) discusses in his “Learning for Mastery” article the correlation between aptitude and time needed to attain mastery of the task at hand. Those students with a higher aptitude for a subject may require less time to learn a task. However, students with lower aptitudes can still master the learning task if given adequate time. Schools must find ways to
provide students the time needed to learn the subject on an individual basis. In elementary schools where teachers are in a contained classroom (all subjects with the same teacher in one classroom) there is more flexibility with time so the needed time for mastery for individual students can be accomplished. In middle schools and high schools where the timeframe for a subject is defined into a set amount the schools will have rethink their schedules allowing students the necessary time to reach mastery. Bloom (1968) determined from Carroll’s (1963) work that the key to mastery is that the individual student is allowed the time needed to learn the task and that the student allocates the time needed to attain mastery.

Carroll’s (1963) definition of perseverance is interpreted by Bloom (1968) as the time a student is engaged in the learning process as opposed to the length of time the student spends on learning a task. Perseverance according to Bloom (1968) will vary with the students’ interest in the task at hand. A student who has struggled with math may give up quickly on a mathematical learning task while the same student may engage for a great length of time in learning a subject that is of great interest to him. Bloom (1968) states that a way to increase perseverance is to make sure that instruction is matched to the student’s ability where the student can find success. Bloom (1968) states, “In our own research we are finding that the demands for perseverance may be sharply reduced if students are provided with instructional resources more appropriate for them” (p. 7). Having the instructional level set at the appropriate level for the individual students allows success rather than frustration. Once the student is successful they will be more motivated to persevere until they reach mastery of the subject they are learning.

The public education system is still caught in the same “educational trap” almost five decades after Bloom’s (1968) “Learning for Mastery” article. According to Bloom schools and research have proceeded with the same standardization of classrooms looking for the one size fits
all curriculum and materials (textbooks) for the group, school district, and nation. Now after 100 years of this strategy with little improvement in public education it is time to seek a different approach and look for what curriculum and material are best for the individual student.

“Carroll’s (1963) defines the quality of instruction in terms of the degree to which the presentation, explanation, and ordering the elements of the task to be learned approach the optimum for a given learner” (Bloom, 1968, p. 4). Bloom (1968) thought that future research should focus on the different types of learners rather than on random assortments of learners so that instruction could be developed to meet the needs of different learner types. Bloom (1968) states, “it is unlikely that the schools will be able to provide instruction for each learner separately” (p. 5). With 1968 technology when Bloom wrote, “Learning for Mastery” this statement would have been true; in 2016 this is no longer the case.

Carroll (1963) interpreted the ability to understand instruction was based on a student’s verbal ability and general intelligence. Bloom (1968) wrote, “The ability to understand instruction may be defined as the ability of the learner to understand the nature of the task he is to learn and the procedures he is to follow in the learning of the task” (p. 5). Differentiating instructional materials to suit a student’s needs to master the learning task at hand is an important part of Mastery Learning. Bloom (1968) was clear in his position that the key to mastery was the ability to modify instructional materials that serve the needs of the individual student rather than a one size fits all instructional model. As he wrote,

The fact that one textbook has been adopted by the school or by the teacher does not necessarily mean that other textbooks at particular points in the instruction when they would be helpful to a student who can’t grasp the idea from the adopted textbook. The task here is to be able to determine where the individual student has difficulty in
understanding the instructions and then provide alternative textbook explanations if they are more effective at that point (Bloom, 1968, p. 6).

In 1968 another textbook could have been another resource. However, in 2016 this could be a differentiated explanation provided by the way of technology. Other possibilities offered by Bloom were workbooks, instructional units, audiovisual methods, and academic games. The purpose of differentiating instruction is to meet the individual needs of a student so that they can achieve mastery of content or skill.

Before Mastery Learning Theory can be successfully implemented in a classroom there are preconditions that must be in place. What will mastery of a subject look like and what evidence will be used as determination of whether as a student has achieved mastery (Bloom, 1968). This will require two forms of assessments to be constructed, formative and summative. Formative assessments need to be built that break down the learning tasks into smaller well defined units and should be used to determine what the student has learned and what learning task the student needs to continue to work on. These should not be used for grading purposes but should be used to determine if a student has mastered the learning task the student is currently working on. Formative assessments reveal what the student has not understood and it must be retaught preferably using alternative methods until the student masters the learning task.

Summative assessments can be given when the student has mastered all of the formative assessment developed for that grading period and can be graded as evidence of a student’s mastery of the subject.

Bloom (1968) discussed many problems with the existing education’s current method of instruction; the normal curve, aptitude tests, group instruction. He did not see that only a select few students could earn an A grade based on a normal curve. Bloom’s research in classrooms in
1967 found that using Mastery learning that 90 percent of his students were given grades of A. In this class he found that the mean performance of the group using traditional methods of instruction compared to the group using Mastery learning methods was about two standard deviations higher than the group using traditional methods of instruction.

Bloom (1968) noted there were significant affective consequences for students using Mastery learning methods. He stated that when a student reached Mastery of a subject “there are profound changes in view of himself [the individual student] and of the outer world” (Bloom, 1968, p. 11). Bloom witnessed that students who achieved mastery became more engaged in the subject and their perseverance and interest in the subject was increased dramatically.

This case study will examine the two classrooms that had significant increases in achievement in mathematics on their summative state tests through the lens of Mastery Learning Theory. Additionally this study will look for evidence of affective consequences that Bloom (1968) discusses in his Learning for Mastery paper for the UCLA Center for the study of Evaluation of Instructional Programs.

**Instructional Methods used in the 5th and 6th grade Classroom in this Case Study**

The mastery learning method implemented in the rural 5th and 6th grade classrooms of the teachers of this study students have a diverse range of math understanding that might range from 2nd grade through 8th grade. In order to address every student’s needs assessments are done to determine what grade level of instruction would be appropriate for the individual student. Benjamin Bloom (1968) stated that one of the preconditions of implementing mastery learning was that mastery needed to be defined so that assessments could be constructed to determine if a student had master a subject. He stated that the summative assessment should be broken into smaller formative assessments for the student to demonstrate mastery of the objective before
going to the next formative assessment. When successfully completing the formative assessments then a summative assessment would be given to the student to demonstrate his mastery of the course. Bloom suggested that third grade math could be broken down to about 35 objectives. The teachers of this study found Renaissance Learning had developed math software with the assistance of the National Council of Teacher of Mathematics (NCTM) that broke each grade level into roughly a hundred or more objectives for each grade level library. There are multiple libraries available that include Common Core libraries and College and Career Readiness libraries. The libraries extend from kindergarten to high school math courses (Appendix F lists the 108 Common Core objectives for 5th grade and the 113 Common Core objectives for the 6th grade).

The teachers used this software to determine students’ grade level and began giving them formative assessments to move them forward in their understanding of mathematics. Each formative assessment was five questions (Appendix G is examples of problems from the 5th and 6th grades Common Core libraries). The examples used are multiple choice however the objectives can also be asked in a free response method. When a student could answer four out of five questions correctly on a formative assessment the student would move to the next formative assessment. The software automatically changed the questions so the student could not simply memorize the answers.

When students could not answer four out of five questions correctly there were multiple ways to teach them how to master the objective of the assessment. They could be assigned a computerized lesson that taught that particular objective. These teachers used multiple software-based lessons that included Compass Odyssey Learning and Kahn Academy. Additionally they could get help from a peer who had master the objective or one-on-one with the teacher. When
the teacher and student decided she was ready to take another formative assessment on the
objective the student could then demonstrate their mastery of the objective. These formative
assessments are assigned to the individual student with every student going at their own pace and
level. This method of instruction has brought about impressive outcomes on summative
assessments showing significant growth classroom wide for high and low students.

When entering the classroom you will see students engaged in their personal formative
diagnostic assessments either on a device or with pencil and paper. Students that did not
successfully demonstrate mastery of a formative diagnostic assessment will be working on an
interactive computer lesson or viewing a video assigned by the teacher, working with a peer who
has successfully mastered the objective the student is currently trying to master, or working
directly with the teacher. The teacher will be assigning formative diagnostic assessment and
assigning interactive computer lesson or videos to student who did not master an objective.
Additionally, the teacher will be teaming up students to help each other to master objectives, and
working with students one-on-one.
Chapter II: Literature Review

A review of the current literature of using technology to improve instruction is the classroom will be investigated in the six following categories:

1. Technology in schools: the need for better math instruction.
2. The Use of Technology to Differentiate Math Instruction
3. The Use of Technology in Mastery Learning
4. The Impact of Technology Use on Student Engagement
5. Using Technology with Face-to-Face Instruction to Improve Efficiency of Math Instruction
6. Mastery Learning

This investigation into the literature is to determine how technology has been used in math instruction in the recent past and present. This should facilitate an understanding of how best educators can best use technology to increase the efficiency of math instruction and increase student outcomes in math learning. Additionally this literature review will inform us of where current use of technology in math pedagogy has been successful.

Technology in Schools

There are many interpretations defining online learning, which constantly change exponentially with the growth of technology. Online education and distance education are often seen as synonymous because distance education is often offered online via the Internet. For the purpose of this paper the Mohamed Ally (2008) definition of online learning will be used. Ally (2008) stated that online learning was the use of the “Internet to access learning materials; to interact with the content, instructor, and other learners; and to obtain support during the learning process, in order to acquire knowledge, to construct personal meaning, and to grow from the
learning experience” (p. 17). Online education does not have to be conducted from a distance but can be delivered in a self-contained classroom. Chris Dede, the Timothy E. Wirth Professor in Learning Technologies at Harvard’s Graduate School of Education asserts that the school classroom will not go away due to online learning, but will use the online technology to customize education for the individual student. Dede (2007) wrote, “At this point in history, the primary barriers to altering curricular, pedagogical, and assessment practices toward the transformative vision of [information and communication technologies] ICT in education … are not conceptual, technical, or economic, but instead psychological, political, and cultural” (p. 35). The need for change in educational pedagogy is due to the fact that the skill brought by students coming to public schools have changed and the skills they need to acquire for becoming productive members of society have altered as well (Edgar 2012; Dede 2007; Kort & Reilly 2002; Papert, 1993).

The digital natives that attend schools today are fully engaged in the latest technology when they are not in schools. They are sitting in front of a television with a computer in their lap and cell phone in their hand multitasking, digesting a sempiternal amount of information. Teachers standing in front of classrooms lecturing and expecting everyone to follow along in a textbook will no longer be able to maintain the attention of these young, tech savvy students. Schools in the mid twentieth century began borrowing from industry the methods of mass production. Class sizes became larger to make use of industries concept of the “economy of scale” making the school costs more efficient. Individual instruction in the large classes became increasingly difficult and the students were traditionally marched through textbooks together. Instructional methods such as these do not allow for the needs of the individual, leaving the less capable students lost and the more capable students bored. These methods were acceptable in an
economy that needed laborers for manufacturing jobs but are no longer adequate for an economy that is knowledge based driven. The Organization for Economic Co-operation and Development (OECD) stated, “Knowledge is now recognized as the driver of productivity and economic growth” (1996, p. 3). The employment opportunities for students coming out of schools require more knowledge based skills due to the increasing technology in the work environment. John Akers, chairman of IBM stated, “In an age when a knowledgeable work force is a nation’s most valuable resource, American students rank last internationally in calculus and next to last in algebra” (as cited in Cuban, 2001, p. 173). President Obama, in his State of the Union Address 2011, stated, “The quality of our math and science education lags behind many other nations. America has fallen to ninth in the proportion of young people with a college degree.” Americans can and must for the sake of the American economy improve education in public schools. Teachers mastering the pedagogical skills necessary to implement online educational practices that differentiate instruction on an individual level in the classroom will bring about significant academic improvement in public schools. Alan November wrote, “As these emerging information and communication technologies continue to have a profound impact on society, one of the most important leadership skills will revolve around helping educators, families and community to let go of existing structures” (p. 5). Americans must move past their psychological fear of change and their political ideology and implement the “best practices” of online educational theories.

Dede (2007) wrote, “In this enterprise of reinventing teaching, learning, and schooling, we would not need to rely on any major technological advances not yet achieved, such as a substantial leap in artificial intelligence” (p. 14). Schools have the necessary resources but have
not embraced the idea of a classroom of students all proceeding at different rates of development or of constructed instructional methods to implement online learning in a K-12 classroom.

Teachers who have been trained to teach the whole class have difficulty making the transition from teacher-centered instruction to student-centered instruction. Terry Anderson (2008) describes this student-centered form of teaching as learner-centered. “Student-centered approaches are theoretically consistent with constructivists’ view of the teaching and learning process” (McCown, Driscoll, & Roop, 1996, p. 419). When online learning is based in a classroom one is not hindered by the problems that distant online teaching can cause in initial assessments. The blending of online learning and face-to-face learning enables teachers to use the best of both worlds. “According to Siemens (2004), we now need a theory for the digital age to guide the development of learning materials for the networked world” (as cited in Ally, 2008, p. 18). With the new technology of online learning, teachers can begin to implement the teachings of John Dewey and Lev Vygotsky where the educational needs of the student are the main focus of instruction.

Dede (2007) wrote, “Education should prepare students for a world in which computers do almost all types of routine cognitive tasks and in which expert thinking and complex communications are the core intellectual skills for prosperity” (p. 13). Creating online learning lesson does not require a unique theory of learning. The teacher must know the different theories of learning and choose the appropriate method for each lesson. Ally (2008) wrote, “Behaviorists’ strategies can be used to teach the what (facts); cognitive strategies can be used to teach the how (processes and principles); and constructivist strategies can be used to teach the why (higher-level thinking that promotes personal meaning)” (p. 20). Technology has advanced to the point that not only are online lessons developed using behaviorist, cognitive, and
constructionist strategies, but also these lessons can utilize a mixture of the three and present them in multiple learning styles simultaneously. Ally (2008) stated, “Strategies should be selected to motivate learners, facilitate deep processing, build the whole person, cater to individual differences, promote meaningful learning, encourage interaction, provide relevant feedback, facilitate contextual learning, and provide support during the learning process” (p. 18). The online learning enables teachers to provide each individual student the optimum lesson to achieve growth without being overwhelmed, keeping them motivated to want to learn more.

Computer software has developed to the point that it can now be used to critique a student’s writing providing instant feedback on: focus and meaning, content and development, organization, language usage, and mechanics and conventions. Teachers cannot provide this amount of instant feedback to a classroom of students nor can they design individual writing assignments based on each individual student’s skills. Online learning makes this seemingly impossible task, possible. Mathematical software is available that will allow a teacher to assign an assessment based on standards selected by the teacher (Common Core or state) that will automatically assign a learning path to work on areas of math that the student has missed on the assessment. This enables teachers to match the difficulty level of the material to be learned to the cognitive level of the individual student.

Students working in a self-contained classroom utilizing online technology will be able to access learning materials on the Internet and also be able to interact with the instructor and other learners on a daily basis. Through this interaction students will be provided ample educational support, which will allow them “to construct personal meaning and to grow from the learning experience” (Ally, 2008, p. 17). It is the interaction between student-teacher, student-student, and student content that educational growth occurs. Terry Anderson (2008) wrote, “John
Dewey’s writings refer to interaction as the defining component of the educational process that occurs when students transform the inert information passed to them from another and construct it into knowledge with personal application and value” (p. 55). Online educational theory is in its infancy and is still developing, but Anderson (2008) has concluded that substituting technology for some of the interaction as long as one of the interactions remains does not harm the quality of the educational results.

The online learning theory as described by Mohammad Ally (2008) where teachers and students access knowledge with the use of technology, that is based on the needs of the individual student allows all students to proceed at their individual pace and at an appropriate level for each individual. Software has advanced today to the point where lessons can be interactive and provide immediate feedback. The individual teacher who is teaching 20 to 30 students cannot provide this kind of support. This ability dramatically increases the efficiency of the elementary classroom and develops an environment that is student centered. The engagement of students can be dramatically increased when they can control the time a student needs to reach Mastery and see a measurable progress. The use of technology in the elementary classroom does not interfere with the interaction between student to students, and student to teachers. Interaction is increased because of the constant learning and desire to share what they have learned with each other.

The Use of Technology to Differentiate Math Instruction: The Research on the Use of Technology Differentiated Math Instruction

Ysseldyke and Tardrew (2007) conducted a quantitative study to determine the effectiveness of progress monitoring using a software program from Renaissance Learning to enable teacher to differentiate math instruction. The software STAR Math from this company
does an initial assessment of each student and gives an analysis of what is the proper level of instruction for the student in the Accelerated Math libraries. These libraries are broken down by grade level based on the National Council of Teachers of Mathematics (NCTM) performance standards. The research was conducted in 125 classrooms (67 experimental classrooms and 58 control classrooms) in 47 schools in 24 states. Because the students were not randomly assigned to the classrooms a t-test was run on pretest NCE scores for experimental and control groups. A t-test is “a parametric test of statistical significance used to determine whether there is a statistically significant difference between the means of two matched, or non-independent, samples” (Fraenkel et al., 2012, G-9). It was determined that the difference was not significant and the results were the same from a t-test run on the scale scores (SS) of the different classrooms. The researchers also ran an analysis of covariance (ANCOVA) to evaluate the effectiveness of program monitoring for students participation in the study. An analysis of covariance is “A statistical technique for equating groups on one or more variables when testing for statistical significance; it adjusts scores on a dependent variable for initial differences on other variables” (Fraenkel et al., 2012, G-1). The dependent variable was posttest normal curve equivalent (NCE) scores and the covariant was pretest NCE scores.

The students in the experimental groups made significant gains over the control group on the post STAR Math assessments. There were significant increases in grade equivalency, NCE, and scale scores in the experimental groups compared to the control groups. Scores were distributed evenly through all quartiles of student abilities showing that the less capable students had equivalent gains compared to the high achieving students. In sum, the study indicated that student being placed at the correct instructional levels is the first step in successful differentiated instruction.
In addition to the above analysis at the conclusion of the study the researchers administered surveys to the teachers who participated in the study. The survey revealed that teachers of the experimental groups thought that students this year were doing far better at: learning basic math skills, attaining higher order math skills, and problem solving skills. Additionally the researchers thought that they had the information needed to diagnose individual students’ difficulties in math. Some of the questions were answered with a numerical answer when asked how much time was spent on various tasks, which revealed that the experimental teachers spent significantly more time in individual instruction than group instruction.

Xin Liang & Qiong Zhou (2009) of the University of Akron conducted a qualitative case study to learn how mathematics is processed when students use technology and what features students feel facilitated learning mathematics when using technology. This qualitative study concluded that, “The repeated instruction and immediate assessment promoted students’ autonomy, encouraged student engagement and nurtured self-directed learning” (Liang & Zhou, 2009, p. 62). The researchers studied two classrooms of a total 55 third graders that incorporated technology into the learning of the standard 3rd grade curriculum. The two classrooms were treated as individual case studies. Two third grade classrooms in two different schools were chosen for the purpose of the cross case comparison and validation of student learning experiences. The majority of students in this study were from lower socioeconomic conditions and over half of the participants were African American students.

Data was gathered by classroom observations that were conducted twice, in fall 2006 and spring 2007, using a specific observation protocol developed by the evaluation team. Additional data was gathered through focus group interviews that investigated the reflection process students engaged in when using technology to learn mathematics. The interview questions
included both open-ended questions and close-ended questions. Open-ended questions provided an opportunity for students and instructors to describe what they were thinking and how it felt to learn mathematics with computer assisted learning. The closed ended questions allowed researchers to find out what features students liked best and what features fitted their specific needs. The results of student experiences were cross-compared by schools and student characteristics. The observation and focus group interview data was triangulated with the themes derived from the three researchers. The results of classroom observations and the coding system were then shared with teachers in the two research sites for member checking. The researchers summarized that computer assisted learning had three unique features that made this method a powerful tool to motivating students to learn mathematics. The computers assisted learning environment made learning fun by having a video game like environment that provided the time for self-exploration and correcting mathematic misconceptions with repeated instruction and immediate feedback. What is not explained in this study are the formative assessments made to determine what lesson each student was being assigned. If they were all assigned the same lesson then instruction would not have been differentiated.

Yigal Rosen and Dawne Beck-Hill (2012) conducted a study based on a mixed-methods design. The data that was collected included standardized assessment scores, school records on attendance and discipline, student questionnaires, and observations in experimental and control classes. The experimental groups were provided individual laptop computers for every student. The researchers gathered data to learn: what was the impact of the program on students’ math and reading performance, student attendance and disciplinary records, learning motivation and attitudes toward learning with computers and instructional and learning practices with emphasis on differentiated teaching compared to traditional classrooms.
The study participants were fourth and fifth grade students and their teachers from four elementary schools from the Dallas area. The researchers sampled the known demographics of schools in this area to find a total of four schools that were evenly matched using two schools as experimental and two as control schools. From these four schools, 476 students and 20 teachers participated in this study.

The impact on the math and reading performance was measured by comparing the 2010 Math and Reading Texas Assessment of Knowledge and Skills (TAKS) scores to the 2011 TAKS scores using a value added model. The impact of the program on student attendance and discipline was collected from the school’s records that were used to see the correlation between math and reading performance with attendance and discipline. Questionnaires at the beginning and the end of the year informed researchers of the impact of the program on math and reading learning motivation and their attitudes toward learning with computers. The researchers qualitatively analyzed and coded data from 55 observations on the experimental and control groups that were used to gain knowledge of the impact of the program on instructional and learning practices with emphasis on using technology to increase instructional outcomes.

The results showed a significant difference in gains on the TAKS test scores for the experimental group over the control group. The experimental group had 29% less absences while the control group had an increase in student absences. The experimental group had less discipline issues while the control group remained the same. Observations also revealed that the one-to-one teacher-student interactions increased significantly in the experimental rooms over one-to-one teacher-student interactions in the control rooms. This study provides evidence that knowledge is not transferred from teachers to students but is a result of a collaborative social constructivism environment (Rosen & Beck-Hill, 2012).
Researchers Valiande and Tarman (2011) conducted a study to determine how, “information and technology can enhance and add to the effectiveness of differentiated teaching in mixed ability classrooms” (p. 169). The study with 30 elementary teachers participation used both qualitative and quantitative methods so that a more precise perspective of the impact of the implementation of technology in the classrooms of this study. The researchers believed the use of the technology let all students receive instruction at their readiness level allowing them to “become ‘constructors’ of their own knowledge and information” (Valiande & Tarman, 2011, p.170). Valiande, Kyriakides, and Koutselini (2011) wrote, “The theory of differentiated instruction is based mainly on the theory of social constructivism (Vygotsky, 1978)” (p. 3). Vygotsky (1978) believed learning occurs in the zone of proximal development (ZPD) and progresses at a greater rate with the assistance of a teacher or more capable peer. He believed that capabilities that already exist do not need to be learned and will not benefit from instruction. Teachers have to meet students where they are academically for students to construct knowledge according to Vygotsky (1978). Vygotsky (1978) distinguished between “the actual developmental level [ZAD], that is, the level of development of a child’s mental functions that has been established as a result of certain already completed developmental cycle” (p. 85) and the potential development (ZPD) of the child. The theory of differentiated instruction determines an individual’s ZAD through formative assessment and then places their instruction at their ZPD with no regard to age, grade, or where other students ZPD level might be in their classroom producing the most effective means of instruction and academic growth for the individual. Valiande and Tarman (2011) concluded from their study that to successfully teach a mixed ability class the instruction would have to be differentiated. “Finding of this study show that differentiated instruction occurs efficiently when teachers implement ICT effectively” (Valiande
They saw that technology could be incorporated into the classroom so that instruction could meet the individual needs so that a mixed ability classroom would not suffer from a one size fits all instructional method.

**Use of Technology in Mastery Learning: Studies that used Technology to Implement Mastery Learning.**

Kent Miles (2010) conducted a study on Mastery Learning and Academic Achievement. The study examined the outcomes of students taught 8th grade mathematics in a traditional classroom setting compared to a classroom using an achievement goal theory with a mastery approach to instruction. The assessment for the comparison between the experimental group and the experimental group was STAR Math a computer-based assessment from Renaissance Learning. This assessment is a norm-based test using a 1400 point scaled score spanning first through twelfth grade. Miles (2010) stated that the validity of the assessment was based on:

- comparing the STAR Math assessment to other tests of mathematics achievement.
- These included the California Achievement Test (CAT), the Comprehensive Test of Basic Skills (CTBS), the Iowa Test of Basic Skills (ITBS), the Metropolitan Achievement Test (MAT), the Stanford Achievement Test (SAT), and several statewide tests. The results indicated a construct validity coefficient of .65 on average in grades 1-12. (p.61-62)

Additionally, Miles (2010) ran a Motivational Orientation Inventory (MOI) that examined students’ motivation concerning: “(a) mastery (task) goal orientation, (b) performance-approach orientation, and (c) performance-avoidance goal orientation” (p. 62).

Both the control group and experimental (treatment) had the same curriculum. The students from experimental group were able to choose their collaborative partners where the
teacher assigned the control groups’ partners. Formal recognition of academic achievement in the experimental group was individualized based on student’s effort and personal growth whereas in the control group formal recognition was based on grades and class ranking. The experimental group would have small group instruction for students working on similar objectives while the control group had no small groups. The experimental group avoided using a grading curve and strived for 80 percent mastery whereas the control group curved test scores and did little in the way of remediation. Students’ in the experimental group set their own pace and were allowed extra time to master objectives whereas in the control group the pacing was controlled by the teacher.

Miles (2010) concluded that the mastery goal structure significantly increased math achievement based on the fact that the experimental group had double the scale score growth of the control group on the STAR Math assessment. The Motivational Orientation Inventory from this study was to “evaluate the motivational orientation of the students, students’ perceptions of classroom instruction, and students’ academic efficacy before and after treatment” (Miles, 2010, p. 109). The results from the MOI data were statistically insignificant other than performance avoidance behavior (Miles, 2010). Miles (2010) concluded that the higher achievement did not significantly change student’s motivational orientation.

A study conducted by Lin, Liu, Chen, Liou, Chang, Wu, and Yuan (2013) entitled *Game-Based Remedial Instruction in Mastery Learning for Upper-Primary School Students* examined the effectiveness of using computer games for remedial instruction using elements of mastery learning design. Lin et.al (2013) stated, “In order to remedy the shortcoming of traditional teacher-centered instruction that ignores the need of students with low achievement, Bloom
(1968) proposed the idea of mastery learning” (Lin et.al., 2013, p. 271). Bloom (1968) asserts that most students can learn given enough time.

A computerized monopoly game was constructed for this study. When the dice was rolled and a student moved on the board a mathematical question would appear for the student to answer. If answered correctly the student could continue to move around the board. If answered incorrectly a video appeared to instruct the student on how the problem can be solved. In order to proceed the student must master the skill needed to solve the math problem. The video could be reviewed as often as necessary to learn the material. Pre and posttest outcomes demonstrate that “the integration of an instructional video based on the concept of mastery learning is beneficial for students learning mathematics” (Lin, et. al., 2013, p. 277). The study concluded “an integration of mastery learning strategies with game-based learning provides greater benefits for students learning mathematics” (Lin, et al., 2013, p. 278). Due to the fact that all students could learn at their own pace, students were able to masters the mathematical content covered in the lessons.

**Impact of Technology Use on Student Engagement: Technology can be used to Impact Student Engagements in the Learning Process.**

Research on student engagement began in the early 1980s as a study on the drop out rate of American high school students and their disengagement from the learning process (Mosher & McGowan, 1985). James J. Appleton, Sandra L. Christenson, and Michael J. Furlong (2008) state that, “The theoretical and research literatures on engagement generally reflect little consensus about definitions and contain substantial variations in how engagement is operationalized and measured” (p. 370). Most researchers agree that student engagement is multi dimensional however they have not agreed upon what those different dimensions are
Finding consensus on a definition of and how to measure student engagement was the goal of Sandra L. Christenson, Amy L. Reschly, and Cathy Wiley (2012) in the publication of their book Handbook of Research on Student Engagement that had over seventy contributing authors in the 39 chapters of the book. In the epilogue of this book they define student engagement as:

Student engagement refers to the student’s active participation in academic and co-curricular or school-related activities, and commitment to educational goals and learning. Engaged students find learning meaningful, and are invested in their learning and future. It is a multidimensional construct that consists of behavioral (including academic), cognitive, and affective subtypes. Student engagement drives learning; requires energy and effort; is affected by multiple contextual influences; and can be achieved for all learners. (pp. 816-817)

Reschly and Christenson (2012) summarized that “student engagement is a burgeoning construct. It is viewed as a basis of theory and interventions related to high school dropout, high school reform, and as a necessary element for improving student outcomes” (p. 17). Much of what is learned from this research can be applied to all students not just high school students.

One accepted theory from the student engagement research is goal orientation theory, which examines the students’ self-perspective on ability, motivation, and self-regulated learning in a highly differentiated classroom. “Goal orientation theorists argue that practices that are used by teachers in the classroom influence student motivation” (Ames & Archer, 1988 as cited in Anderman et al., 2001, p. 77). The highly differentiated classroom viewed through the lens of the goal orientation theory lens can examine the effect of students’ self-perception using this instructional method. “From an engagement perspective, students who hold mastery goals are
likely to be more cognitively, emotionally, and behaviorally engaged with tasks because the overarching “goal” is task mastery” (Anderman & Patrick, 2012). Online technology allows students and teachers to track objectives (tasks) that have been mastered which demonstrate a student’s growth.

**Technology with Face-to-Face Instruction to Improve Efficiency of Math Instruction: A Combination of Online Teaching and Face-to-Face Learning can Increase the Efficiency of Student Growth in Mathematics.**

Jeffery S. Drysdale, Charles R. Graham, Kristian J. Spring, and Lisa R. Halverson of Brigham Young University in an analysis of research being conducted in the area of what currently is called blended/hybrid learning found 205 dissertations or theses that were relevant to their definition of blended learning (2012). The definition used in this study was based on Charles R. Graham’s definition in the Handbook of Blended Learning: Global Perspectives, Local Designs (2006) “blended learning systems combine face-to-face instruction with computer-mediate instruction” (p. 6). The search was conducted in the ProQuest Dissertation and Theses Database (PQDT) due to the fact that “PQDT receives 97.2% of all dissertations and theses from research universities in the United States (276 of 284) and 87.2% (41 of 47) of those from Canadian research universities” (Davies, Howell and Petrie, 2010, p. 45). When these dissertations and theses were examined and analyzed by the researchers they found that the studies were equally divided between quantified inferential and qualitative studies. Approximately half of the studies were focused on learner outcomes, which included: performance, satisfaction, engagement, effectiveness, motivation and effort, independence in learning, and retention rates (Drysdale et.al, 2012). There was little research found before 2008 in K-12 schools and "only five instances of K12 instruction qualified for the analysis, leaving a
need for further study on the subject” (Drysdale et.al, 2012, p. 4). A closer look at the research reveals that the K-12 studies are mainly high school blended programs with little reference to elementary schools. Additionally the researchers of this survey found that theoretical frameworks for the 205 studies they looked at were weak and that “few researchers used theoretical frameworks to shape their research questions” and that there was a “significant need for more theoretical contributions unique to the context of blended learning” (Drysdale et.al, 2012, p. 17). Researching the use of technology in education can be difficult due to the fact that the use of technology can be different not just from classroom to classroom but from student to student in a single classroom. Due to the fact that blended learning is in its infancy theoretical frameworks and terminologies have not been entirely solidified (Graham 2013; Drysdale et.al, 2012; Picciano, Dziuban, & Graham, 2014).

Heather Staker and Michael B. Horn note the differences between postsecondary and K-12 education (Blended learning in the K-12 education sector, Chapter 19 in Picciano, A. G., Dziuban, C. D., & Graham C. R., Blended learning: research perspectives vol. 2, 2014). One thing that Staker and Horn acknowledge is the in locos parentis role that the K-12 schools play in today’s society. Children need a safe place to be while parents are working during the day. This fact changes the way blended learning can be implemented in K-12 schools due to the fact that students are on site and instruction with the use of technology can become more personalized in comparison to a strictly on-line instructional method. Blended programs vary from school to school with variations on the amount of time spent on instruction versus direct instruction. Staker and Horn (2012) wrote a white paper for the Innosight Institute (renamed in 2013 the Clayton Christensen Institute after Harvard Business School luminary) to help establish a blended learning taxonomy so that K-12 schools could have a common language in which to
better communicate in discussions, collaborations and research. In their study they looked at approximately 80 different programs where they found four distinct clusters of methods that met their definition of blended learning. Staker and Horn (2014) defined blended learning as:

> A formal education program in which a student learns at least in part through online delivery of content and instruction with some element of student control over time, place, path, and/or pace and at least in part at a supervised brick-and-mortar location away from home; (p. 290)

The model below in Figure 1 depicts the four discrete forms of blended learning Staker and Horn (2014) found from their 2012 study of blended learning models.

*Figure 1. Blended Learning Taxonomy*
Their rotation model is broken down into four different models of rotations:

- **Station rotation.** This can be groups or whole class moving from online learning and direct instruction on set time schedule or teacher’s prerogative.

- **Lab rotation.** The students rotate on set time schedule to a computer lab for online learning instruction separate from the classroom.

- **Flipped classroom.** Direct instruction in the classroom with online learning done off site often as homework.

- **Individual rotation.** A more personalized student centered approach model of rotation between online learning and direct instruction. The rotation schedule is based on the individual needs.

The second blended learning model that Staker and Horn (2012) found from their study was what they called the Flex model. They found many models that were variations of the flex model where the main part of instruction was online learning. The teacher can alter instruction in a flexible manner providing the individual student the support needed to be successful. This can come in many forms: small group instruction, scaffolding with peers, and one on one instruction from the teacher. Additionally, teachers can assign individual online activities to target an area where students are struggling.

The A La Carte model is the third model that Staker and Horn (2012) identify in their study. This model is a combination of online learning courses and traditional courses. The online courses are virtual courses that are not supplemented with any face-to-face instruction. These courses are not blended learning but allow the student to attend other classes in a brick and mortar school to experience the environment of the brick and mortar school. The courses that
are not online are taught in the traditional manner with face-to-face direct instruction methods. The students can work on their online courses at school or at home choosing when and where they will work on these courses.

The fourth model that Staker and Horn (2012) identified was what they referred to as the Enriched Virtual Model that is a combination of face-to-face instruction with off-site online learning. This model differs from the Flipped Classroom due to the fact that students do not attend the brick and mortar school on regular weekday daily schedule. Staker and Horn (2012) found that many of these schools started out as online schools and then added the brick and mortar to create a blended learning model that could provide extra support for students so they could have success in their learning experience.

Mastery Learning

**Mastery Learning: 1968 ~ 1976.** James H. Block and Robert B. Burns (1976) conducted a survey of the studies on mastery learning that they believed was “the best of the mastery learning to date” (p. 13). The criteria for their search of studies were that the study was conducted in a school environment and were based on typical school objectives (Block & Burns, 1976). “The research we sought had to employ learning task that were meaningful, complex and relatively long” (Block & Burns, 1976, p. 13). Block and Burns (1976) only used studies that were pre-experimental, quasi-experimental and true experimental designed and where the experimental and control groups were probabilistically equivalent. Block and Burns (1976) looked for master learning studies in published books, journals, unpublished papers from research meetings, and unpublished dissertations.

The studies collected by Block and Burns (1976) were broke into four types of research: Type 1 studies examined if mastery learning was more effective than traditional methods
answering the question “Does it work” (p. 14). Type 2 research examined the affective and time consequences of mastery learning. The third types of studies investigated the effect of mastery learning for different kinds of learners and are there some components of mastery learning that work better than other components. The fourth type of research that Block and Burns (1976) referred to as an emerging field of research was why does mastery learning work and how do you implement it.

Block and Burns (1976) stated that research in the Type 1 category demonstrates that mastery learning does work. “In quantitative terms, mastery approaches have usually produced greater student learning than non-mastery approaches, and they have usually produced relatively less variability in this learning” (Block & Burns, 1976, p. 25). From a qualitative perspective master learning has helped student learn higher order thinking.

The affective consequences examined in the Type 2 research concluded that “mastery strategies have had a positive impact on students’ interest in and attitudes toward the subject matter learned, self-concept (academic and more general), “academic self-confidence, attitudes toward cooperative learning, and attitudes toward instruction” (Block & Burns, 1976, p. 26). The second part of the Type 2 research found that the slower students using the mastery learning methods overtime began to work more efficiently which led to a homogenous effect in regards to the issue of time class-wide. Block and Burns (1976) stated “Our student time cost data suggest that mastery strategies might eventually help slower students to learn more like faster students do” (p. 32). The research indicates that students that initially works slower than some at first may eventually work at the same pace as their peers over time.

The research from the third category concluded that the most important component of mastery learning is the unit mastery requirement. Block and Burns (1976) wrote “we would
hypothesize that the reason the unit mastery requirement and the meeting of that requirement have exerted such an influence over student learning is because they have affected the quality and the quantity of student study time” (p. 35-36). Studies that failed to maintain strict unit mastery requirements showed less student achievement and retention than the studies that kept stringent requirements of unit mastery before proceeding to the next unit.

The Type 4 area of this research looks at materials that have created to instruct teachers on how to implement mastery learning. There have been materials written by Block and Anderson (1975) on implementing mastery learning in the elementary classroom. Okey and Cielsa (1975) developed a module instructing elementary and junior high teachers how to implement mastery learning. Anderson and Block have developed mastery-training material for the college level. The Type 4 research concluded there are materials for training pre-service and in-service teachers how to implement mastery learning strategies in the classroom.

Block and Burns believed “that the most important practical implication of the research is that mastery learning strategies may represent one of those major breakthroughs to the improvement of student learning for which the educational research and development community has been searching (e.g., Krathwohl, 1974)” (Block and Burns, 1976, p. 38). The theoretical implications of this study show the need for learning theories to be developed in the school environment rather than in laboratories due to the fact that laboratory developed theories are sometimes difficult to implement in the classroom (Block and Burns, 1976). Block and Burns (1976) express their concerns that the ideological implications are that the vast majority of teachers do not have faith in the fact that most students can reach mastery of material. Mastery learning provides evidence that teachers have underestimated the capabilities of students to learn.
Mastery Learning: 1976 ~ 1986. Thomas R. Guskey and Sally L. Gates (1986) gathered studies on group based mastery learning from the Educational Resource Information Center (ERIC), Dissertation Abstracts, and the Psychological Abstracts databases. Additionally a manual search was conducted through Glenn M. Hymel’s Mastery Learning: A Comprehensive Bibliography. Guskey and Gates (1986) decided, “Since the Block and Burns review was judged to be fairly complete summary of the research conducted through 1975, we focused our search on articles and manuscripts that appeared after that year” (p. 74). The initial 234 potential articles were reduced to 27 that dealt with elementary and secondary education. The criteria to be included in this review was the study had to be group based, had to report on measured outcomes for students mastery learning groups and control groups, and to be free of methodological flaws (Guskey & Gates, 1986). The studies were quantified to include: time variables, student affect, student achievement, student retention, and teacher variables.

Guskey and Gates (1986) meta-analysis of the 27 studies that met the criteria for this review concluded that student achievement for the mastery-learning group was extremely positive when compared to the control groups. “To quantify the outcomes of these studies we used effect size, a statistic calculated by taking the difference between the means of the treatment and control group and dividing that difference by the standard deviation of the control group (Glass 1976)” (Guskey and Gates, 1986, p. 75). A +1.0 would be considered a significantly positive outcome. This would mean the experimental group achieved a level that only the top 15% of students in the control group reached (Guskey & Gates, 1976). The effect size for student achievement in grades 1-6 was .89 and for grades 7-8 was .92. The effect size for student achievement for grades 9-12 was .72. “All of the 25 elementary and secondary school studies reporting achievement outcomes showed positive effects as a result of the application of
group based mastery learning strategies” (Guskey & Gates, 1986, p. 74). The mastery learning strategies proved to be effective in all grades especially elementary and junior high schools.

The time variables for mastery learning showed an effect size of .68. Bloom (1971) stated that mastery learning would reduce the differences of time needed between the faster learners and slower learners. “Learning rate does appear to be alterable and mastery learning procedures may be one way slow learners can be helped to increase their rate of learning” (Guskey & Gates, 1986, p. 77).

From the group of studies in this review three of the studies investigated retention of learned material (Guskey & Gates, 1986). One course in 8th grade Algebra found the effect size of mastery learning to be .62 after the both groups were tested two weeks after the completion of the course. Another group tested both groups on learned material three weeks after completion of course and found a retention rate of .51 favoring the mastery-learning group. The one study that did a long-term investigation was an elementary study that tested retention four months after the completing instruction. “The retention of mastery student was again found to be significantly greater with an effect size of .52 (Guskey & Gates, 1986, p. 77).

Only one study in an elementary school measured student affective variables. The study measured student’s attitude toward the subject being learned and their own self-concept of their learning abilities (Guskey & Gates, 1986). Students that were in the mastery group overall like the subject better than control group with an effect size of .41 and were more confident about their abilities with an effect size of .49 over the non-mastery group.

Teacher variables were the last area to be investigated by this review. Teachers using mastery learning methods begin to believe that their instruction practices and behavior are more
important (effect size 1.13) than personality factors (effect size .38) (Guskey & Gates, 1986). As they wrote,

Guskey (1984) found that teachers that use mastery learning and see improvement in student learning outcomes begin to feel much better about teaching and their roles as teachers (effect size .61), accept far greater personal responsibility for their students’ learning successes and failures (effect size 1.25), but express somewhat less confidence in their teaching abilities (effect size -.59). (Guskey & Gates, 1986, p. 78)

Guskey & Gates (1986) believe that is important to conduct master-learning studies in actual classrooms rather than is a laboratory classroom. The disadvantage of conducting studies in actual classrooms, acknowledge by Guskey and Gates (1986), is that there will many variables that cannot be controlled. Additionally the problem of precision in the treatment has as many variables as there are students in the classroom. Overall Guskey and Gates (1986) wrote, “the research evidence reviewed here indicates that the use of these strategies [mastery learning] can result in significant improvements in a broad range of student learning outcomes and teacher variables (p. 79).

**Mastery Learning 1972 ~ 1986.** Chen-Lin C. Kulik, James A. Kulik, and Robert L. Bangert-Drowns (1990) conducted a meta-analysis study on the effectiveness of mastery learning programs. To find studies for their meta analysis a search was conducted through two library databases that were the Educational Resources Information Center (ERIC) and Comprehensive Dissertation Abstracts. Additionally a second source was material referenced in the original articles retrieved from the databases. The selection of studies to be included in the meta-analysis had to meet four criteria: students taught using mastery learning methods are compared to students using traditional methods, mastery method be no less than 70% on
assessments, methodology must be robust without flaws, and must contain quantitative results large enough to evaluate effect (Kulik et al., 1990). There were 108 studies that met the selection criteria.

End of course assessments was the most common outcome measured in the 108 studies. Other variables that were measured included: retention, attitude toward instruction and subject matter, course completion, and the time needed for learning (Kulik et al., 1990). The studies that reported end of course assessment scores, which were 103 of the 108 studies, reported positive effect for all but 7 studies. “Also, 67 of the 96 studies with positive effects reported that the difference in amount learned by experimental and control groups was great enough to be considered statistically significant” (Kulik et al., 1990, p. 271). These studies showed an increase from the 50th percentile to the 70th percentile on end of course assessments.

Of the eleven studies that did follow up assessments all showed a positive effect in retaining the instruction from the use of the mastery learning method. A more positive attitude was found in 16 of the 18 studies that addressed the variable of attitude toward instruction. Twelve out of the 14 studies that addressed the variable of attitude toward subject matter found a more positive attitude in the classes that used a mastery learning method. Course completion rate in the traditional methods of instruction was slightly higher than the mastery learning methods. The groups that used mastery learning methods compared to traditional methods needed slightly more time for instruction (Kulik et al., 1990).

The findings from this study concluded that mastery-learning methods made a positive impact on summative assessments, attitudes toward instruction and attitudes toward subject matter (Kulik et al., 1990). Additionally this study concluded that the affects of mastery learning were more significant on the weaker students and did require slightly more instructional time.
The studies in this literature review show that mastery learning is an effective method of instruction that will produce more positive outcomes on summative assessments than traditional methods of instruction. Additionally it reveals the ability to differentiate instruction down to the single student using technology also contributes to increases academic outcomes on summative assessments. Combining mastery learning with a blended learning environment can greatly impact math instruction in the elementary classroom.
Chapter III: Methodology

Rationale for a Case Study Design

To examine how the teachers in this study increased math achievement in their classrooms there are to many variables to conduct a quantitative research method so a qualitative method was chosen (Stake, 1995). Every student’s needs were addressed individually daily causing a constantly changing environment of instructional methods being implemented. Quantitative data does show that outcomes on summative math assessments were significantly greater in the two classrooms of this study than the normal classroom however it does not explain how or why this occurred. To answer these questions a qualitative approach is best suited to answer how and why the two classrooms produced greater math achievement on their math summative assessments. This mixture of quantitative and qualitative data asking how and why can best be examined with a case study approach (Yin, 2003).

The researcher will write a description of the case within in its setting and boundaries simply stating the facts of the case adding this to the database (Creswell, 2009). The boundaries for this case study will be looking at growth in mathematics in two classrooms rural Alaska classrooms. The growth on state summative assessments, STAR Math assessments and MAP from NWEA assessments in mathematics by these two classrooms over many years is significant and this study will be looking for how and why this occurred by interviewing the teachers administrator, and students from these two classrooms.

This qualitative case study inquiry presents how students’ achievement in math was achieved from the perspective of the participants (administrator, teacher, and students) and how the blended learning environment inclusive of the use of technology affected students’ engagement and achievement in learning mathematics. A study that reveals the methods of
using technology in math instruction to significantly improve the effectiveness of math instruction will be a valuable addition to the current body of empirical evidence on differentiated instruction. The two classrooms of this study have consistently produced significant improvement of student outcomes in mathematics summary assessments (Appendix E) and these methods have been proven to be transferable to other teachers and classrooms.

A case study will bring more insight to how these two classrooms had significantly better outcomes than other classrooms in this rural Alaskan community whereas a quantitative study would only reveal the already known fact that these three classes had superior outcomes on the Alaska Standards Based Assessment in mathematics. When one is seeking an explanation of how and why a phenomenon occurred a case study is an appropriate method of research (Yin, 2005). The use of a qualitative case study is appropriate due to the fact that little research has been done on the use of technology in mathematics instruction in elementary classrooms and “qualitative research is exploratory and is useful” when the phenomenon is complex in nature (Creswell, 2009, p. 18).

**Site and Participants**

The setting for this case study is a rural community public elementary school in a school district in southeast Alaska. Ketchikan Gateway Borough School District (KGBSD) is located on the Revillagigedo Island off the coast of the mainland in Southeast Alaska. The main industries of the island are tourism, fishing, and government work (e.g. coast guard, forest service, local government).

The school has approximately 350 students of which: 43 percent are Caucasian, 33 percent are Alaskan Native, 15 percent are Asian, 3 percent are Multi Ethnic, 2 percent are American Native, 2 percent are Hispanic, and the remaining 2 percent are classified as other.
Forty-eight percent of the student population is economically disadvantaged. The classrooms in this case study consist of students from one 5th grade classroom and one 6th grade classrooms. Focus groups will be conducted with several former cohorts of students having been in these classrooms. The teachers that will be interviewed one 6th grade teacher and one fifth grade teacher. Additionally, the building administrator of the school during the time frame being used in the case study will be interviewed.

**Study Context**

This study examined mathematics outcomes on three different kinds of summative assessments. The first is the Alaska Standards Based Assessment (SBA) that was used from 2006 thru 2014. The Data Recognition Corporation (DRC) that was founded in 1978 as a testing and surveying company, worked with Alaska to develop the SBA based on Alaska State Standards to meet the NCLB testing requirements. The second summative assessment is STAR Math from Renaissance Learning, which is a skills based assessment of math achievement. The predictive validity average on over 45 studies involving over 45 states involving over 60,000 students in math had a validity coefficient of 0.70 for 5th grade and 0.73 for 6th grade (STAR Assessment, 2014). The validity for internal consistency in study of over 2 million 5th and 6th grade students was 0.93 (STAR Assessments, 2014). The third assessment is the Measure of Academic Progress (MAP) from Northwest Evaluation Association (NWEA). Educators and researchers in Oregon and Washington founded NWEA in 1973. This nonprofit organization’s goal was to create a new kind of testing tool to measure individual student’s academic level and growth. Currently over 10 million students use the MAP assessment annually to track academic growth.
The Ketchikan Gateway Borough School District (KGBSD) tracked the growth and progress of students and teachers by using a value added model based on the outcomes of scores on the Alaska Standards Based Assessments (SBA). The difference in scale scores from spring to spring determined the amount of growth or regression of students. The chart in Appendix E shows the value added average outcomes for the fourth, fifth, and sixth grade teachers’ students in the KGBSD. The blue bar represents the year 2013 and the red bar represents the average outcomes from 2008 through 2013. Two teachers averaged over double the growth of the fourth ranked teacher in this school district with nearly half of the teacher’s averages regressing year after year. The intellectual goal of this study will be to determine how these two teachers had significantly higher outcomes in mathematics than the rest of the fourth, fifth and sixth grade teachers in the Ketchikan Gateway Borough School District.

In 2013 the elementary school of this study began using MAP from NWEA to monitor student growth. On the summary growth report is a column marked School Conditional Growth Percentile which is a metric that shows how students growth compares to the approximately 10 millions students that take the MAP assessment annually. This measurement allows for comparison of projected growth to other schools across subject areas and grade levels. The school of this study’s 5th grade is in the 99 percentile and the 6th grade in the 97 percentile of the conditional growth index for the approximately 10 million students that take the MAP assessment annually. Both the Alaska SBA and MAP are based on a Rasch model. The SBA scale is designed to measure horizontally (grade level criteria) and the MAP scale was designed to measure vertically (overall growth from year to year). The MAP according to Richard M Smith (personal communication November 10, 2016) editor of the Journal of Applied Measurement recommended using the “MAP data due to the availability of the data across
cohorts and the superior scale properties when studying growth.” The MAP and STAR Math give us grade equivalency data due to the fact that they measure vertically which gives educators greater insight to overall growth in comparison to the Alaska SBA, which will give results to the mastery of criterion of a single grade level.

Data Collection

The qualitative data was gathered came from a variety sources. As Creswell (2007) states, “The data collection in case study research is typically extensive drawing on multiple sources of information” (p. 75). Data was collected in the form of interviews, focus groups interviews, and participants’ stated observation. Focus groups was formed with the students who participated in the classrooms involved in this case study. There were one-on-one, face-to-face interviews with the teachers and administrator involved in this case study. The focus group and interview protocols for each stakeholder group can be seen in Appendices and include open-ended questions that allow interviewees to talk and the interviewer to listen and take notes (Creswell, 2007; Stake, 1995).

Two teachers, one administrator, and current and former students of Ketchikan Gateway Borough School District who participated in and/or were affiliated with the math program being studied were recruited for their participation. Recruitment letters for students were sent to the parents of students. Students were be selected based on who was willing to participate irregardless of gender, ethnicity, academic levels or socio-economic levels. The primary researcher conducted the interviews at any location the participant chooses outside of normal school/work hours. The teachers and student focus groups were interviewed following the interview protocol forms in Appendix A and B. Interviews for all participants were recorded and transcribed using Rev transcription services that provide the data that was used for analysis. The
interviews for the administrator and teachers were conducted by the researcher and were approximately 60 minutes. Student focus group interviews were 30 to 50 minutes and the researcher conducted these interviews.

**Data Analysis**

Data analysis is an ongoing process that begins when the data is first being collected until final interpretations. Stake (1995) wrote, “There is no particular moment when data analysis begins. Analysis is a matter of giving meaning to first impressions as well as to final compilations” (p. 71). The transcribed interviews were organized into a data bank and read through for analysis. The analysis was coded “begin with open coding, coding the data for its major categories of information” (Creswell, 2007, p. 64). From this data axial coding was conducted which looked for categories that reveal how the research question will be answered (Creswell, 2007). From an analysis of the codes and categories, themes were developed that contribute to an explanation as to how and why this growth in mathematics occurred. This process was done individually on the data collected from each group, administrator, 5th grade teacher, 6th teacher, and student focus groups. The themes from the different groups were then brought into summary themes built from the perspectives of all groups combined. The coding process is often cyclical according to Saldaña (2013) where the researcher will code and then recode. The researcher used an interpretivist view that relied heavily on naturalistic methods to determine what are the unique characteristics and differences in these two classrooms that led to the significantly different outcomes in mathematics.

**Validity and Credibility**

Researcher constructed validity by using many sources of evidence, having a cumulative amount of evidence and have key participants review case study (Yin, 2009). Researcher will
build internal validity by thorough matching of coding process, explaining the choice of analytic data units, addressing other possible explanations of results and why the conclusions drawn are correct. Using proper protocols for case study and showing that the data will produce the same results with repeated procedures of the case study.

**Protection of Human Subjects**

The researcher received approval from Northeastern University Institutional Review Board for this case study. An explanation of the purpose of the study was given and explanation of how the answers to the questions will be used and assurances of their anonymity of their responses to questions in interviews. Written permissions were signed before any interviews took place (Stake, 1995). All interviews were recorded, transcribed and done face to face. The interviewees will be offered a copy of their interviews once they are transcribed (Creswell, 2007). All participants will were informed about the research that was conducted in their classroom. After an explanation of how the research will be conducted to the students and their parents a written explanation of the research to be conducted was provided. Earnest T. Stringer (2007) wrote that written consent documents should include:

1. People have the right to refuse to participate.
2. They may withdraw from the study at any time.
3. Data related to their participation will be returned to them.
4. Any information (data) will be stored safely so that others cannot view it.
5. None of the information that identifies them will be made public or revealed to others without explicit and written consent. (p. 55).

Stringer (2007) further states that teachers engaging students in routine matters such as, “find[ing] better ways of attaining learning objectives” may not require formal consent (p. 55).
However, it would be wise to acquire written consent so that students and parents are fully aware of the research being conducted and what their participatory role will be. It is imperative that checks are put in place to ensure the trustworthiness of the action research study (Stringer, 2007). Four attributes to assess in a study: credibility, transferability, dependability, and confirmability, are suggested by Lincoln and Guba (1985) to establish the trustworthiness and rigor of a study (as cited in Stringer, 2007). This will lead to assuring the truthfulness and validity of a research study.

**Conclusion**

There are significant differences in the outcomes on the state summative assessment in mathematics than there are in the remaining 20 or more classrooms in this school district. This case study’s goal was to reveal the reason for these significant differences in outcomes on state summative mathematics test so that this information can be shared with other colleagues in this school district and throughout Alaska so that more student can reach Mastery in Mathematics.
Chapter IV: Research Findings

The purpose of this case study is to understand why mathematical achievement was significantly higher in two classrooms employing blended learning across multiple years in a rural Alaskan elementary school as perceived by the administrator, two teachers, and students from these classrooms. While the quantitative data shows a consistent significant difference between the classrooms in this study and other classrooms in the school, district, and state on summative assessments it does not explain why this has occurred. By interviewing the adults and students involved in these classrooms and examining their perspective on why the academic growth in mathematical outcomes was significantly higher in their classrooms might recommend instructional strategies that can be put to use in other classrooms to increase student achievement as well.

Below are the perspectives of the former administrator of the school, the two teachers, and several students having experienced the program that is the subject of this study.

Administrator’s Perspective

The principal of the school with the two classrooms under review in this study went to graduate school at the University of Southern Alabama and earned a Master of Education and began working as a teacher in the school district that this study is conducted. In 2005 he became the principal of the elementary school with the two classrooms being reviewed in this case study that had failed to make AYP on the 2004 state test. This was his first year as an administrator and teachers in the building approached him and expressed their concern that a new 5th grade teacher, which is the researcher of this study, was not following the adopted school district’s curriculum.
When he called the fifth grade teacher to his office to discuss the issue the fifth grade teacher brought the school district’s math curriculum with him. The 5th grade teacher proceeded to explain why this curriculum would not lead to successful outcomes for the 17 Title I students and 5 ESL students in his classroom. This teacher had purchased eight Dell computers with his own money and explained to the administrator how he would individualize the students’ instruction in his classroom that would lead to greater growth for the students in his classroom. The teacher said that he would stand by the outcomes on the state test. And, in the end, his students ended up with greater growth than all of the fourth, fifth, and sixth grade teachers in the school district. The administrator allowed the fifth grade teacher to continue this method for the next six years that he was the administrator of the elementary school of this case study.

Four themes emerged from the coding and analysis of the administrator’s interview were derived from a close review of administrator’s interview, asking how he perceived the two classrooms identified achieved significantly more growth on summative assessments than the other teachers in the school district. The four themes identified are as follows:

- The classroom environment increased student engagement.
- The differentiation was individualized for every student.
- The students preferred the instructional methods.
- The state standards and grade level expectancies were taught to directly.

The classroom environment increased student engagement. The administrator noted that when he entered these classrooms that all students were engaged. When the administrator was asked about the environment of these rooms he stated:

the environment; I think one of the things right off the top, kids were engaged. They were doing things. If we're looking at math time, for example, when you go in there at math
the kids are all engaged. They weren't doing things that they had already done. I mean for the most part they were doing new things.

Additionally, the administrator noted that the environment of these classrooms resulted in strong positive relationship between the teacher and students. The administrator found it to be interesting:

that I think a lot of people would miss when you think about that kind of a classroom, is the kids actually [made] good connections with their teachers, because when they did [need] help they could go to their teacher and say, Hey I need help on this one particular area. I think that built a good relationship between the teacher and the student.

The positive relationships within the classroom were further strengthened by student-to-student relationships due to the fact the teacher would allow a student who mastered an objective to help another student who was struggling with that objective. The administrator stated, “teachers would use other peers to help as kind of peer helpers. I think that was really good. It built relationships that way too.” Overall the administrator found the environment to be positive which contributed to the outcomes of these classrooms. The relationships built between the teacher and the students and the student-to-students created an atmosphere of high expectations where a sense of community was built among all those who participated in the classroom.

**The differentiation was individualized for every student.** From the administrator’s perspective the “biggest” difference from the classrooms of this study and the other classrooms in the building was the individualized differentiation that was implemented in the classrooms of this study. As he said, “Rather than having groups of kids working at one rate or another thing or whatever it was, the kids were all able to meet their area of need and progress at their pace to a large degree.” The administrator saw this individualized differentiation as beneficial in
comparison to the “traditional classroom” due to the fact as points out you only reach a portion of the classroom with traditional methods. He saw the problem with the “traditional classroom” to be that,

25% of the kids don't get it because it's too hard. 25% already get it so they're not engaged. You're only kind of teaching to the middle and that just disappeared in those classrooms where the kids could go at their own pace and deal with the material that was...relevant to them.

Because the material for the individual student was relevant to the students needs the student becomes more engaged in the math objective. The administrator stated, “I think the kids were more engaged because they were doing stuff that mattered to them personally. They weren't working on fractions if they already knew how to do fractions.”

**The students preferred the instructional methods.** He stated that some staff had expressed concerns about the methods being used in these classrooms and said “that maybe kids hated this and it was an awful thing and that the kids wouldn't like it.” When the administrator began talking to students to find out how they felt about what was going on in the classroom he found out that for the students “the lion's share, it was positive. They liked what they were doing. They liked their teacher. I think that was good all the way around.” Additionally the administrator found that a key component benefit was the immediate feedback that could be given to each student by the programs being used. The administrator believed that the immediate feedback kept students from “wondering” how they were doing on assessments and thought this was “positive even if the results were not.” Due to the fact results were known instantly, “that if they were hung up on something, they could get help immediately. That's always a good thing too. There wasn't this quagmire of waiting to see what's going to happen next or whatever goes
with that. I think that's real positive.” The administrator noted that the self-concept of the students became more positive as they realized that they could become successful academically in a math class. This led to more engagement in the learning process and less classroom management problems. The administrator stated that the instructional methods used in the classroom helped with classroom management. As he said,

I think if it's managed well ... I think one of the things, as long as the kids, the expectations are there, again, basic classroom management things, and a teacher moves and does what they need to do I think it does help with management of kids for sure.

Overall the administrator found the blended instructional methods being used in the classrooms of this study were liked by the students that led to increased engagement, less classroom management problems and positive academic outcomes.

The state standards and grade level expectancies were taught to directly. The Alaska State Standards developed in the 2005 developed grade level expectancies for each grade level so teachers had a clear concise understanding of what expectations for each standard meant for each grade level. For example for multiplication for 5th grade students were expected to be able to multiply two digits by two digits. The teachers of the classrooms in this study developed tests that would test students on all of the grade level expectations for their grade level in mathematics. The administrator believed one of the major reason that the classrooms of this study greatly impacted mathematics outcomes was due to the fact that the teachers in these classrooms were making sure that students had mastered the grade level expectations of the state standards. The administrator stated,

I'm sure they had kids that couldn't meet those expectations that they started lower that worked up towards them, but the target was right in front of the kids in a couple of the
classrooms to the point where I saw the GLEs written on the board and the kids were keeping track of which ones they've mastered. I see that as real positive.

The administrator was aware that this led to each student working on the grade level expectation that they had not mastered so the individual students in the classroom could all be working on the math objectives that pertained to the individual rather than the rest of the students.

From the administrator’s perspective the: classroom environment, the individualized differentiation, the instructional methods, and directly addressing the state standards and grade level expectancies are what led to a significant increase in mathematic growth and outcomes in the classrooms of this study.

**Teacher Perspective – 6th Grade**

The 6th grade teacher of this study is a National Board Certified Generalist teacher for students ages 7~12 from the state of Washington. Both of her parents were educators and she originally began her college studies in “cognitive neural psychology.” The 6th grade teacher stated, “I decided after learning what I did that I wanted to apply [this knowledge] in the classroom.” The 6th grade teacher explained that when she began teaching the “reading workshop literacy model was coming into prominence.” In the district that she was working in Washington there were some of the national leaders in this field. The 6th grade teacher stated “I went to study with them, and just learned about differentiation with literature, and finding meaningful texts, and reaching kids where they were developed mentally.” When she asked her colleagues what they were doing about math instruction she said they responded, “they don’t teach math.” The 6th grade teacher stated that, “They just don’t teach it. They spend all day on literacy, and they would get 4 to 5 years’ worth of growth with their kids every year, and they would send math home in a packet for parents to do.” At this point in time this 6th grade teacher
stated that she decided she would try to “replicate the success I had with literature in a math setting.”

The 6th grade teacher described how in her effort to replicate her success in literature in a math setting she, “worked as a lab classroom teacher and a mentor teacher for the National Council of Teachers of Mathematics (NCTM), and I had a state … like a liaison. I worked with State Superintendent’s Office, and we would take the math textbook and completely deconstruct every lesson.” She described the arduous task of differentiating every lesson as,

It would take us hours per lesson, and we would create differentiation, create multiple modalities, create formative assessments, and all of that was done by hand as we went every day for every lesson, and so it was a form of mastery learning, but the technology wasn’t there to make it something that was transferable.

The 6th grade teacher expressed that she did not think that many teachers would dedicate the time it was taking her to optimize every lesson for every student and acknowledged that even with all the hours she was spending she was not at “100%” of what was needed. In 2008 the 6th grade teacher moved from Washington to Alaska and began teaching at the elementary school that is the location of this case study. The 6th grade teacher stated,

When I came here, 2008, and was introduced to the technology that was doing for me automatically what I had been doing for hours every day after school by hand. It was like a big … an instant like the last puzzle piece came into place. It made it possible for me to do what I knew was best for kids in a practical way.

The 6th grade teacher of this case study has been using in her own words, “a form of mastery learning” harnessing technology to achieve significant growth in mathematics in her classroom since 2008.
Four themes emerged from the coding and analysis of the 6th grade teacher’s interview:

- Increased student engagement improved student’s self-concept.
- Student centered instructional methods increases mathematical achievement.
- Technology can be used to differentiate to the individual student.
- Students master their current objective before being moved to the next objective.

**Increased student engagement improved student’s self-concept.** The 6th grade teacher’s thought that when instruction is adjusted to the individual student’s ability and students find success their engagement increases and their personal self-concept improves. The 6th grade teacher found that by using the blended model instructional methods she was introduced to in Alaska it changed the dynamics of student engagement and the students own views of their ability to master mathematics in her classroom. The 6th grade teacher stated,

   A lot of times, kids who felt they were unsuccessful in the past, their coping strategy is to disengage, so they don’t even want to attempt to try to feel like there is much of a chance they’re going to be successful.

The 6th grade teacher found by adjusting, “the task in front of them [students] is appropriate to where they’re at developmentally” and the students began experiencing success; “Suddenly, there’s a lot more engagement from the kids, classroom management is less of an issue, their self-concept changes.” When the 6th grade teacher was asked how teaching math in this blended model benefitted students she stated that students every year would:

   walk in the door and say, I suck at math. I’m terrible at math. I can’t do this, because their previous experience has usually been having material thrown at them one day, and the next day, we move to the new topic.
As she said, this would happen without the students getting the opportunity to master the objective before them. The 6th grade teacher stated, “many kids every year that once they start to see themselves as capable of learning and mastering new objectives, it’s really transformative.” She found that even the students who started slow that, “their pace begins to increase as their foundational skills increase and their confidence increases.” The 6th grade teacher shared her perspective on how student engagement increased when the students began to believe they were capable of being successful. When talking to students at the end of the year with students about their outcomes on major assessments and their grade she would have students tell her things such as: “I used to think I could not do math, and now, I can do this, converting decimals to percent,” or, “I used to think that … I used to hate math, and now, it’s so easy for me.” Observing these changes in her students changed the 6th grade teacher’s own self-concept. She stated the role in the classroom using this blended model had changed her role as the teacher compared to a traditional role of a teacher. As she said,

The role in this case is more guidance, and management, and oversight, administering assessments and follow-ups, tracking progress, holding students accountable as opposed to just delivering information, and it requires me to be aware of multiple different activities happening at once in different levels of math. Maybe multiple grades of math, but more in a coaching way than in a talk-down way.

The 6th grade teacher stated that when she began teaching that she believed the “perfect scenario” would be a one-on-one or a small group of students. She was looking for a method of delivery that makes that possible with 25 or 30 students. When she began using the blended model of instruction she stated she felt, “a lot more effective as a teacher.” She enjoyed seeing the increased engagement and success of her student, “but to be able to see that translated into
quantifiable numbers is pretty rewarding.” The 6th grade teacher found that the methods she was using increased student engagement and improved the students’ perspective on their ability to be successful at mastering math and her belief that she had the ability to make that happen for her students.

**Student centered instructional methods increased mathematical achievement.** The 6th grade teacher believed that her instructional methods were student centered which led to greater growth due to the fact that the students’ instruction was relevant to the individual student. The 6th grade teacher in her interview explained that the instructional methods of her classroom were not the traditional model that was teacher centered rather than student centered. She referred to the traditional method as the textbook method and stated: “it’s very different from a textbook method where it’s one instructor delivering information at the same pace and the same timeframe to a very diverse group of learners, which is usually not successful for most of them.” The 6th grade teacher explained that through technology all lessons could be individualized to meet the needs of the individual student. She expressed that her method was different than the traditional method in that there was a, “lot of student self-direction.” The 6th grade teacher further explained that, “the task in front of them is appropriate to where they’re at developmentally, and then if they need further instruction, they have a lot of options to self-select.” The 6th grade teacher explained that when they do not understand a math objective in front of them they have multiple alternatives to receive assistance such as: “They might decide to have a peer help them. They might work with an aide or me. They might decide they want to go use some math software and get a video lesson.” She expressed that she believed students if given enough time and proper instruction would be able to master the objectives they are asked to complete.
The 6th grade teacher expressed her concern about the misconstrued ideas of how she was using technology in her classroom. The 6th grade teacher expressed this as follows:

You see some of the misconceptions about it maybe from people who have seen students just left alone in front of a computer or if there’s no follow-up, if the kids don’t have accountability, if they’re not being assessed with each objective.

The 6th grade teacher discussed the importance of students knowing that what students do on-line is being closely monitored and that they are provided needed feedback on how to improve their understanding and mastery of objectives. She also discussed “decision points” in the online assignments. These decision points, usually set at 80 percent mastery, will block a student from going further in their assignments until they master the current assignment at a minimum of the 80 percent level. She thought, “it’s human nature to perform better when you know that what you’re doing matters and that somebody is paying attention.” The misconception was the students were “just going to click through.” She expressed when students realize that they will be held accountable it changes their engagement level.

The 6th grade teacher acknowledged that these methods were not the traditional methods however, she stated that, “it seems unlikely that continuing to do the same method and the same model over and over for decades is going to ever result in different outcomes for kids.” The 6th grade teacher expressed that, “you don’t necessarily have to work within a traditional delivery method and traditional textbook method to be rigorous, and focused, and standards-driven.” The outcomes in mathematical achievement on summative assessments from this 6th grade teacher’s classroom would indicate that to be a true statement.

Technology can be used to differentiate to the individual student. The ability to differentiate to the individual with the use of technology provided a way to achieve what had
been the 6th grade teacher’s goal in Washington as a lab classroom for NCTM and liaison to the state superintendent. The 6th grade teacher when coming to the school of this study found two other teachers using technology to differentiate instructions down to the individual students in their classroom.

Before coming to Alaska she stated that this is what she was trying to create by hand in Washington. The 6th grade teacher stated the technology is:

the piece that makes it possible to differentiate to this degree. There is an instructional component to it. There’s an assessment piece. I have the ability to track, and kids know that I’m keeping them accountable, and it’s a lot more engaging than a traditional textbook or worksheet. There’s animation, and activities, and interactive games, so the kids are more engaged. The materials are created, so I’m not reinventing the wheel every day, and the pacing is able to be differentiated.

In the 6th grade teacher interview she explained how with the technology she could accommodate for the individual pacing meeting each students needs. Using the technology the necessary assessments were picked that showed mastery of the state standards. The students would work through these objectives one at time, not moving onto the next objective until they had mastered the objective that they were currently working on. The sixth grade teacher stated, “You start with what the kids need to know and be able to do, and give them the tools to work through those objectives.” Through the use of technology the 6th grade teacher was able to explain how she could accommodate for the individual students learning speed and learning style. The teacher explained that the class was equip with “one-to-one devices” that enabled each student to be working on different objectives at their own pace and those students that had finished their sixth grade objectives could move on to upper grade levels. The 6th grade teacher stated that, “there
are multiple avenues for kids to choose the method that makes most sense to them, and it’s another thing that the technology provides, variety.” She believed the reason she was able to achieve the significant growth in mathematical outcomes on summative assessments in her classroom was due to the fact she was, “able to work with the kids where they’re at with the differentiation that the technology provides.

**Students master their current objective before being moved to the next objective.**

When the 6th grade teacher was asked why she thought that the student growth in math was much greater in her blended learning classroom than other classrooms she responded:

 Definitely the mastery learning; the fact that the kids aren’t going to be asked to do things they can’t do and they’re not going to be promoted ahead to new ideas unless they really have a deep understanding and it’s embedded in their long-term memory.

The 6th grade teacher went on to explain that she believed this was achieved by breaking down the overall lessons into smaller objectives that could be mastered one at a time. She stated from her experience she had “never seen kids integrate information to a long-term memory from just seeing it once in a textbook lesson, and then at the end of the year, you get to the accumulative test, and they remember everything they’ve been taught.” The 6th grade teacher expressed that mastery meant students should be able to apply the objective they had mastered, “to projects and presentations [and] to mentoring other students who are still working on those same objectives.”

The 6th grade teacher’s class average showed 2.7 years grade equivalency growth on their STAR Math Growth Report and was in the 97 percentile in their School Conditional Growth Percentile on the MAP assessment of NWEA (over 10 million students in this norm referenced test) for the 2015-2016 school year. The class began the year with a class average RIT score of 219 which is two points above the norm for a beginning 6th grade class. The RIT score average
for the 6th grade teacher’s class on their spring MAP test was 233.1. The norm for a beginning 11th grade class is 233.3. This class had statistically significant growth in mathematics for the 2015-2016 school. The 6th grade teacher has consistently gotten this kind of growth in mathematics from her students over many years.

**Teacher Perspective – 5th Grade**

The 5th grade teacher of this study began teaching 5th grade in 1976 when he graduated from college in Washington. After three years of teaching he went into the grocery business running grocery stores. He had put himself through college working in grocery store and was offered work managing grocery stores, which he did until 1990 when he returned to the teaching profession. His experience in the grocery business became a part of his teaching style where everything was data driven. The 5th grade teacher saw student growth as profit gain or profit loss. He stated, “coming from my grocery experience, if we weren't on top of say your profit loss, we couldn't wait a year to find out if things were doing okay.” The 5th grade teacher went on to compare gathering data as the equivalence of keeping track of inventory in a grocery store. To determine if students were making gains was like tracking perishable goods in a grocery store stating that, “until you determine that you were losing money in any of those perishable areas, then you would ... Inventory once a week. Sometimes once a day, until you found out where the problem was.” When discovering how he could use technology to take an inventory of his student’s individual gains and losses it change his perspective on his role as a teacher from the “sage on stage” to being the “facilitator” of his students education.

Three themes emerged from the coding and analysis of the 5th grade teacher’s interview:

- The 5th grade teacher believed student engagement was greatly increased when instruction was adjusted to the individual student’s ability and pace.
- The 5th grade teacher believed the ability to differentiate instruction to the individual student with the use of technology greatly increased the academic growth in mathematics.

- The 5th grade teacher believes that by differentiating the instruction to meet the individual students needs on their own time line all students can achieve mastery of the objectives.

The 5th grade teacher believed student engagement was greatly increased when instruction was adjusted to the individual student’s ability and pace. The 5th grade teacher believed that by adjusting instruction for the lower and higher student that “We’re looking at a stronger engaged rate.” He stated that once instruction was adjusted to the appropriate level irregardless of what level they came in at that, “When they see that it's productive, and if it's individualized towards them, they tend to put out more effort for a sustained about of time.” The 5th grade teacher had 8 to 12 students that rotated depending on who did not have another afterschool activity stay afterschool each night to work on math. Due to the fact that the math is online students can work at home on a computer or on their smart phones. Engagement had increased this year to where the 5th grade teacher informed his class not to do math after 9:00 and “Don’t call me after 9:00.” The objectives record a time when a student submits their work. The 5th grade teacher would check to see what was submitted the night before when he came in to school in the morning. When he saw a student had submitted an assignment at 10:36 the night before so he asked the student:

How does that work with you and your family? Do you all stay up and work? He says, "No, I was in bed." He was in bed with his smartphone, doing his math. That's not too
often, that you have somebody doing that if everyone is on page 57 and you're doing problems 1 through 35, even if you're doing the odd or even ones.

The 5th grade teacher noted that the students hunger for learning math was dramatically increased by the individualized and self pacing methods of instruction he incorporated in his classroom. Time allowed in the classroom during the day was not sufficient to satisfy their appetite for learning math. He stated:

I'll get phone calls during the night or on weekends to discuss certain objectives, certain math topics. Typically it's the, "Feed me, Seymour," type of thing. That's from the Little Shop of Horrors. They will want more during the off school hours. We find that it empowers the student, because they can see that what effort they put into it, they can excel rapidly.

The 5th grade teacher noted while most of his class has the technology at home to access their math instruction in the current year there were three students who did not, however he could accommodate their needs by printing their work to take home with them to do in a paper and pencil method.

The 5th grade teacher was particularly impressed with one student’s intense engagement in the current year that he described as “very veracious.” He said this boy had mastered, “832 objectives for the year” and was surprised that he was not leading the class in objectives mastered. The 5th grade teacher stated that, “There was another gal who was in stealth mode and she was calling me all year, talking about math, working during the day. She had 838.” He further made it clear the minimum expectations was two objective a day and that, “I never held a sorter hammer over them. They just did that because that's what they wanted to do.” The 5th grade teacher in his interview inferred that one grade level was approximately 140 objectives.
He expressed that these student had done “a fair amount of work.” The 5<sup>th</sup> grade teacher expressed that he did not think you would find this kind of engagement in your traditional textbook instruction. He stated, “I'd say 98 percent, 99 percent of the kids who thought that they could not do math, that math wasn't for them, they experienced success. They have it tailored to them at their level. They have voracious appetites for it.”

He stated due to the increased engagement they did not have discipline problems during math instruction. The 5<sup>th</sup> grade teacher stated:

> We just don't have kids that act up during math. They might at recess. They might when they're out in the general population, but their intent ... Because it's special to them and it's targeted to them. Again, I don't play the organ, but it seems like more of a conductor. If I can just keep those kids going to the area that they need to be in, and that they buy into it then, too. When they experience success and they can just keep moving, I just facilitate that.

The 5<sup>th</sup> grade teacher was clear that one of the major factors contributing to his classes’ exceptional growth in mathematics was the increased student engagement in learning math brought about by adjusting the level and time allowed for the individual student to master each objective.

**The 5<sup>th</sup> grade teacher believed the ability to differentiate instruction to the individual student with the use of technology greatly increased the academic growth in mathematics in the classroom.** He stated, “It's just through the use of technology, of some human resources, and analyzing the data, that we're able to meet the mathematical needs of each student.” The 5<sup>th</sup> grade teacher stressed throughout his interview that by using the technology in his classroom instruction was tailored to the individual student. He stated that with the
technology, “I'm able to assess and react more rapid than without it. I can tell fairly quickly [determine] where the kids are and where their mastery level is.” The 5th grade teacher inferred that he could go in as many directions as he had students. This year he had 22 students and stated he could adjust quicker “to the 22 different directions that the kids are going into. He expressed that the technology allowed for the differentiation that was needed and stated:

Now with the use of the technology and my deeper toolbox, we can get to the needs of each child, to their level of success and where they may need to start stepping up to get towards grade level achievement or to get to their personal expectations.

The 5th grade teacher discussed that with this technology students that were above grade level could be challenged and their individual needs could be met as well. Beginning in 2005 the 5th grade teacher began looking for resources beyond the textbook “to meet the vast disparity in grade level abilities” in his classroom and “what it would take to meet their needs.” He further stated that at this time “we started to look at things like Compass [software from Odyssey Learning]. This software allowed for building lessons to let individual students work on achieving mastery of math objectives. The 5th grade teacher explained that one of the additional ways that the technology is used to differentiate instruction to the individual student was using the Measure of Academic Progress (MAP) assessment “available through the Northwest Education [Association] (NWEA). He explained, “That has given us a chance to assess the students on a trimester basis in the fall, and then we can make adjustments with the students' needs, as determined by that test, and then use the Compass Learning program.” The Compass program interfaces with the MAP assessments and then gives students lessons based on their individual outcomes. The 5th grade teacher stated with the combination of these two programs, “We've been able to get individual learning paths for the kids as a result of that testing.” He then
talked about the software that is the heart of the mastery portion of this math instructional method, “We also use Accelerated Math [from Renaissance Learning].” The 5th grade teacher stated, “The current library that I'm using goes up to 1,800 objectives for the kids. At each grade level, I believe there's maybe 140, 145.” He explained that the students are “working through their objectives.” The 5th graded teacher explained that,

Now the objectives as determined by grade level, as determined by assessments, on what they're strong at and where they're weak. That's why I found that this one Accelerated Math program helps me individualize better.

These individual assessments will determine what the individual student will do next. The 5th grade teacher stated, “We have an electronic submission of their work and it'll tell them immediately what they have done right, what they have done wrong.” While students will move to the next objective if they correctly answer 80 percent of the questions the 5th grade teacher explained,

we'll still investigate that one they missed. Usually it's a head slapper. ‘Oh, I just made a mistake doing this.’ I still ask them to show me their work. They still have to have their work attached to it, so that we can do that investigation.”

This process is where mastery learning in a blended environment begins.

The 5th grade teacher believes that by differentiating the instruction to meet the individual students needs on their own time line all students can achieve mastery of the objectives. When the 5th grade teacher discussed outcomes for student using his previous traditional method, which he described as the “sage on the stage” he clearly knew he was not reaching all the students. He stated,
if I were to go back to 1976, when I was fresh out of school and into a 5th grade classroom of ... I think I had 28 kids. We were trying to hit them all with the same lesson to all the kids. It would be like the one blanket is not going to cover everybody. The majority of the kids, the average range, it was 5, but I was losing the high kids, losing the low kids. That seemed to be about as good as I was going to be able to do with the tools that my new teaching experience, which wasn't very deep.

The 5th grade teacher when discussing how he began teaching originally stated,

Almost 40 years ago now. I could sit down right now and write up my lesson plans for next year out of my textbook. If I had a couple of weeks and I said, ‘Okay, I want to get that knocked out,’ I would just get my textbook and my lesson plan and just write out what I'm going to do in math. We'd know what page we're going to be on and what unit we were going to do and when we were going to do ... Hopefully, we'd catch as many kids as possible.

The 5th grade teacher discussed his role had now changed to that of a facilitator with his focus getting every student to the area that they need to be in. When students demonstrate that they have not mastered an objective the teacher had many ways to help them master the objective before them which included the use of technology, peer to peer support and one on one with teacher or an adult.

When explaining how the different ways the technology could be incorporated he stated, “we can take them to a mini lesson on Compass. This year, we've been trying more on the Kahn Academy also, which has been a terrific help.” One of the advantages the 5th grade teacher discussed was when you find an area that a student has weakness in a certain strand explained:
We'll catch a place value. Say, "Well you see, they've had some holes in their place test, so I can take them down to the third grade." There's maybe 10 objectives at 3rd grade. If they master that, then we can take them through that same strand.

He continued to explain that you could then give them objectives on that strand in the next grade level and proceed until they master their current grade level. The student does not have to do all of the other grade level objectives just the ones that they are weak and the 5th grade teacher pointed out this is not so easily accommodated when using a textbook method. When the 5th grade teacher was asked how does he know if a student has mastered an objective he responded:

Through the accelerated math, we can look at each individual objective of that child and we can make adjustments on that one. We'll look for retention on that every other week, and then we'll come back and see how that student has retained that information.

The 5th grade teacher’s class average showed 2.7 years grade equivalency growth on their STAR Math Growth Report and were in the 99 percentile in their School Conditional Growth Percentile on the MAP assessment of NWEA (over 10 million students in this norm referenced test) for the 2015-2016 school year. The 5th grade teacher has consistently gotten this type of outcomes for the last 10 years using this unique form of instruction. This student growth is statistically significant compare to most forms of instruction.

**Student Perspective**

The students interviewed were from both the 5th and 6th grade teachers’: 2015-2016, 2014-2015, and 2013-2014 classrooms. Twenty-four students participated in small focus groups ranging from two to five students each with with an age range of 10 to 15 years in age. Seven male students and seventeen female students participated in the focus groups. The academic
proficiency of students participating in the focus groups ranged from low-average to high mathematical academic ability.

Three themes emerged from the coding and analysis of the student’s interviews:

- Students expressed how self-pacing and instruction differentiated to their ability benefited their growth in mathematics.

- Students in the focus group viewed the use of technology-based programs beneficial to their ability to master their personal math objectives.

- The students that had gone on to junior high and back to the traditional textbook method of instruction became frustrated when classroom instruction moved forward before they had mastered a concept.

Through out all the focus groups students expressed how self-pacing and instruction differentiated to their ability benefited their growth in mathematics. The students stated that being able to work at their own pace worked for them much better for them academically than being tied to a class pace. One student stated how going at his own pace helped him from becoming overwhelmed by his math lessons. The student stated:

I think it helped to learn math a lot better, because I was at my own pace and I could know what I was working on and I felt good on what I was working on. Instead of having like being a couple chapters back and like the math class I have now. Feeling like, I can't do this problem, I can't do this set of problems, I'm going to work on this one. Just feeling overwhelmed by it.

All students saw the advantage of being on their own path not to having to wait or be slowed down by the abilities of another student. One student expressed this with his statement:
Being at your own pace and knowing what you have to do. You don't have to feel like you need to catch up. Being like you feel like you don't have to slow down and wait for everyone else to catch up. You can just go as far as you can.

Students that had struggled in math prior to having a self-pacing form of math instruction found that they were able to master mathematics and begin to enjoy mathematics. A student expressed this in her statement:

I remember when I was little I would always have a hard time because they would go very quickly. So I'd be left behind. But now I can go at my own pace without worrying about other people going very fast or too slow. So it's helpful when you're on your own.

Students who always excelled at math articulated that the self-pacing method increased their engagement and relieved their boredom during math instruction. A student who had never struggled in math stated, “I liked the individual path because when I was little and we didn't have individual path things, I felt like I just had nothing to do. I was just like uhhhh I know this already.” Due to the fact everyone could proceed at their own pace meant that they could also proceed at their own ability level. Students recognized the importance of starting at the developmentally appropriate level of instruction. This reflected in the comments made by students such as: “it helped me with my mathematics. It helped me advance in it, because it leveled out with me.” and “doing it by yourself, in your own personal level, it's a lot easier, because it's more of a challenge for me.” All the students realized that their math instruction was individualized; many referred to it as their “individual learning path.”

Students in the focus group viewed the use of technology-based programs beneficial to their ability to master their personal math objectives. One student stated that when they would have a low score on a formative assessment their teacher would give them options, which
included a lesson on a computer program or getting help from a peer who had mastered that objective. Another student stated that use of technology assisted with mastering objectives due to the fact that the computer lesson “really helped on showing examples of it” and “was good to because you could get video on a certain lesson.” Many students liked the fact that with the use of technology you would get instant feedback. One student expressed this in their statement, “I think that using technology really helped, because you instantly saw if you got the questions right or wrong and you could go back and fix them and then correct yourself.” Another student stated this in their statement:

you could see what you got wrong and you could go back and learn it and if you still didn't get it you had like you said Kahn Academy and Compass and it just made it a lot easier to understand what you're learning.

Some students stated that they preferred the use of the technology over the traditional paper and pencil format because they found the work easier to do in a format that they were more use to. One student expressed this in his statement:

because we used more technology, and that's, honestly, easier for me to use and recognize better than seeing it on paper. Sometimes it's a lot easier for me to look at and understand it on the electronics sometimes, because it's something that's more familiar and I use more often now.

Consistently throughout the student focus groups students appreciated the fact that with the computers all students’ objectives could be adjusted to their personal abilities. One student stated, “it's good when we're on the computers on the individual learning paths. It's good cause it kind of feels like you are learning more”
Many students found the convenience of having their math online made it easier to keep track of their work unlike homework in a packet. One student expressed this in his statement, “A lot of times my backpack is a huge mess, and I cannot find anything. Having it just online is a lot easier.” From the discussions in the student focus groups it was evident that the technology was appreciated by the students and increased their engagement.

**The students that had gone on to junior high and back to the traditional textbook method of instruction became frustrated when classroom instruction moved forward before they had mastered a concept.** One student that moved from their 6th grade school to the junior high school where they were using the traditional textbook method with a pacing guide stated:

If you get behind on one section today and then you move on to the next section you need the knowledge from that last section to be able to do this. You end up getting further and further behind, because you never mastered that first section.

When students were to make a comparison between the instructional methods they experienced in 6th grade to their current instructional methods one student stated:

For me it was like if you're on something that was hard, you could not understand it a hundred times and keep getting them wrong, but you didn't move on until you absolutely knew it. Now they just expect you to know it every single day, you just keeping moving forward even if you can't understand what you did before.

Many students expressed their frustration with statements like: “They're kind of just rushing you, they just want to get it over with. If you don't get something, they'll just move on without you.” and “if you fall behind, then you can't do the next lesson.” All of the students who had been in the 5th and 6th grade teacher’s classroom of this study had been instructed in a method that
required them to master their current objective before they could move on to the next objective. Moving back to a traditional textbook method where you keep moving forward to the next lesson based on a pacing guide students realized the importance of mastery of objectives in mathematical instruction before moving to the next lesson.

**Summary of Findings**

The findings of this case study are based on the interviews of the administrator, 5th grade teacher, 6th grade teacher and student focus groups of a rural Alaskan elementary school. It is evident that everyone interviewed believed that the significant gains in mathematics were accomplished by allowing every student the time needed to master each objective before moving on to the next objective. Due to the use of technology-based programs every student was given instruction that matched his or her ability as described by participants as their “individual learning path.”

By objectives being matched to what students described as “levels” they were able to find success through the support of computer based lessons, peer to peer help, and one on one instruction from their teacher. This success according to the administrator, 5th grade teacher, and 6th grade teacher led to significant increase in student engagement and subsequently student learning. Children want to be successful; all you have to do is build them a path.
Chapter V: Discussion of Research Findings

Revisiting the Problem of Practice

The outcome of math scores on the Program for International Student Assessment (PISA) was coordinated by the Organization for Economic Cooperation and Development (OECD). The United States continues to lag behind other countries ranking 35th out of 64 countries that participated in the 2012 PISA assessment (National Center for Education 2016). The National Center for Education (NCES) (2016) reported that:

In 2012, average scores in mathematics literacy ranged from 368 in Peru to 613 in Shanghai-CHN. The U.S. average mathematics score (481) was lower than the average for all OECD countries (494). Twenty-nine education systems and two U.S. states had higher average mathematics scores than the U.S. average score and nine had scores not measurably different from the U.S. score.

Nationwide educational reform movements, such as NCLB and now Common Core, have had little impact on mathematical assessments scores by American students on international assessments.

Hess (2010) discussed the difficulty of reform in all bureaucracies stating that “size, habit, and an established position left them lumbering and heavy footed” (p.14) like elephants, and unable to respond to the current needs of the consumers. Hess (2010) refers to Economic Turbulence (2006) by Claire Brown, John Haltiwanger, and Julia Lane that states that the average life span of a Fortune 500 company is 50 years. The authors that worked 50 years ago may not work in the present day. Most of the 13,500 public school systems in the United States were established many decades before 1966. Hess (2010) states, “There is not a single sector
where widespread efforts across hundreds or thousands of organizations have resulted in dramatic gains in quality” (p.12).

The importance of improving education in American schools as seen by the Council of Foreign Affairs Independent Task Force report on the United States Education Reform and National Security report stresses the importance of improving education in American schools and notes that it is imperative to securing our economic future. "Educational failure puts the United States' future economic prosperity, global position, and physical safety at risk," (Klein, et. al., 2012, p.4) warns the Task Force, chaired by Joel I. Klein, former head of New York City public schools, and Condoleezza Rice, former U.S. secretary of state. The country’s K-12 education "will not be able to keep pace—much less lead—globally unless it moves to fix the problems it has allowed to fester for too long," (Klein, et. al., 2012, p. 58). Richard N. Haass, (Klein, et. al., 2012) President of the Council of Foreign Affairs, stated that students leaving schools today do not have the math and science skills needed to work in modern industry. Employers are recruiting foreign-born people for STEM positions for their companies due to the fact that they cannot find US citizens who have the needed skills. These foreign-born employees increase American costs according to a study conducted by Magnus Lofstrom and Joseph Hayes (2011) comparing U.S. born employees’ earnings to the earnings of foreign born H-1B visa employees. H-1B visas are issued for applicants that have a specialty skill that employers cannot find in US born applicants to fill positions needed. Lofstrom and Hayes (2011) concluded, “that overall H-1B workers in STEM occupations have higher earnings than their otherwise observationally similar US born counterparts” (p.14). A research brief by Jonathan Rothwell and Neil G. Ruiz (2013) determined that 90 percent of H-1B visas were STEM related.
The American K-12 public schools have to improve mathematic instruction if the United States is going to compete economically with the rest of the world.

**Discussion of Major Findings**

Interviews with teachers, administrator, as well as student focus groups, multifarious themes emerged that helped determine why these classroom’s yielded the tremendous growth in mathematics achievement. Four major themes were identified from the interviews with the teachers, administrators, and student focus groups. They are presented in Table 1.

Table 1

*Major Findings from the Study*

<table>
<thead>
<tr>
<th>Student engagement will increase dramatically when instruction is adjusted to the students’ ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individualized learning paths for every student with the use of technology</td>
</tr>
<tr>
<td>Self pacing of instruction moving toward student centered learning</td>
</tr>
<tr>
<td>Mastery of state standards defined by objectives to be learned.</td>
</tr>
</tbody>
</table>

**Student engagement will increase dramatically when instruction is adjusted to the students’ ability.** As seen in the fifth grade teacher’s interview the teacher had to set a 9:00 PM deadline for students calling to ask that more math objectives be assigned to them online.

Students in a traditional textbook driven, teacher-centered classroom do not call their teacher at home and ask a teacher to assign them more work as reported by the 5th grade teacher. Teachers and administrator reported that when instruction is adjusted to the individual student’s ability and they experience success they become more engaged. For many students this is a new form of mathematics instruction encouraging increased engagement because they enjoy that experience.

The 6th grade teacher reported that this experience appeared to contribute to a change students’
self concept and that they no longer believed that they “sucked at math.” As reported by students, teachers, and administrators, sole reliance on teacher centered whole class instruction has the opposite impact causing students to disengage. A fifth grade student summed up what all parties expressed reporting that by having her math assignments individualized it “relieved their boredom during math instruction” and her feelings about sitting through a whole group instruction was noted as, “uhhh I know this already.” The administrator reported the other end of the spectrum when describing the teacher centered traditional classroom approach stating “25% of the kids don't get it because it's too hard” and went on to say “that just disappeared in those classrooms” referring to the classrooms of this study. Participants reported their belief that the reason the method used by these teachers demonstrates multi level grade equivalency increases every year is that students are not limited to their current grade level, but rather explore assignments at their instructional level resulting in increased student engagement. If they are in fifth grade objectives they quickly find out that if they master their entire current grade level objectives they will be given objectives from the next grade level to work on. It is evident that the people interviewed in this study believed adjusting instruction to the individual student’s instructional level increased student engagement.

**Individualized learning paths for every student with the use of technology.** The teachers, administrator, and students all reported that having individualized learning paths greatly improved their mathematic achievement. The 6th grade teacher described the ideal, perfect scenario for teaching would be if I could instruct “one student, the content, the level, and the method of delivery.” With the use of technology the 6th grade teacher stated, “I make that ideal possible in the reality of 25 or 30 kids in the classroom.” The technology was used to administer formative assessments that determined the individual needs of every student. This
information was used to determine instructional level and assignments for each individual student. The 5th grade teacher stated “if it’s individualized towards them, they tend to put more effort for a sustained amount of time ... We find it empowers the student, because they can see that what effort they put into it, they can excel rapidly.” Through this method students were not working on objectives they had already mastered but working on new objectives that they needed to learn. The technology provided a method for teachers to assign individual lessons to students as needed to master new objectives. Students reported that the computer lesson would give them examples of how to work the problems of their current objective and additionally provided video lessons that greatly increased their understanding of the objective. Many students stated that the instant feedback provided by the technology makes it easier to correct any errors regarding the correct method of working on of their current math problem.

It is the educational technology that allows the individual students to access a variety of avenues to learn the math objectives and this can enable most learning styles to be addressed. The teachers and administrator reported that without the technology to differentiate instruction and assignments to the individual student the significant gains on summative math assessments would not have been attainable.

**Self-pacing of instruction moving toward student centered learning.** The students reported the importance of self-pacing for themselves for them to be successful in mathematics study. Students that moved out of elementary school and in to the junior high found themselves back in traditional textbook classrooms. These students were frustrated by their experience and reported that they struggled with a concept the teachers would still go on to the next section whether or not all students understood the current objectives. One student stated when comparing his 7th grade math class to his experience in his 5th and 6th grade math class, “It’s a
lot of my own pace and not the teacher’s teaching everybody at one pace. It was my own pace and it was a lot easier than falling behind.” Another student stated, “Yeah, it’s definitely a lot like more teacher oriented” when describing his 7th grade math class. The students realized that math is taught in a linear sequential developmental method. They found when they went to the next section of the book and had not mastered the objectives of the previous section they experienced difficulty due to the fact they did not have the skills needed to master the new objectives. Several students with high mathematical skills reported that they were forced to slow down and wait for others in the class to catch up, and that led to lessening of their enthusiasm during math class. Teachers, administrator, and students all found that the ability of students to proceed at their own pace was a crucial element in the students’ increased math achievement.

**Mastery of state standards defined by objectives to be learned.** The administrator and teachers reported that significant increase in the state test in mathematics was due to the fact that the teachers developed tests that made sure every student had mastered all of the grade level expectations that they would be tested on. There were approximately 100 small formative assessments that would inform teachers if students were prepared for the state assessment. Objectives that would not be on the state test were still taught with the same mastery expectation. When Alaska had a state test (we currently do not have one) the state test was built from Alaska grade level expectations that were built from the Alaska state standards. The math standards in most states are broken down to performance expectations by grade level for all grades. Matching the formative assessments in Accelerated Math to the performance expectations that are to be tested for any grade level can give teachers the opportunity to determine if each individual student has mastered the performance expectations for their grade level. As an example a 5th grade level expectations for math was a student should be able to multiply two digits by two
digits. A formative diagnostic objective from Accelerated Math that tested a student’s ability to multiply two digits by two digits with five questions would be administered. If the student got four out of the five questions he was moved on to the next grade level expectation. Once a student had mastered all of the grade level expectations they could begin working on the next grade level. All students proceeded at their own pace and level through the grade level expectations. When they had mastered one grade level they moved to the next grade level. Retention of material was checked periodically and anything not retained was re-learned. The test used for 6th grade expectations was 136 questions administered four times before students took their state test. Using this method the classrooms were consistently prepared and successful on the Alaska Standards Based Assessment in math.

Discussion of the Findings in Relationship to Mastery Learning

Mastery Learning is based on the belief that most students can achieve mastery of a subject if an individual is given the time needed, exhibits perseverance, has the ability to understand instruction, can, and is provided quality instruction (Carroll, 1963). Building on this idea, Benjamin S. Bloom (1968), over a three-year period 1965 through 1967 at the University of Chicago’s lab school, implemented a mastery-learning classroom. Ninety percent of the students in Bloom’s classroom were able to achieve mastery (an A grade) by his third year. Bloom (1968) stated that there were preconditions that needed to be met before you could implement a mastery learning strategy in a classroom.

In order to determine if a student had mastered a subject or skill, the teacher must specify the objectives a student must master and determine the assessments specific to these objectives so the student can demonstrate her or his mastery of the subject. Bloom (1968) stated, “We must be able to define what we mean by mastery and we must be able to collect the necessary
evidence to establish whether or not a student has achieved it” (p. 8). Bloom (1971), as an example of objectives needed stated “in third grade arithmetic, there may be about 25 learning tasks arranged in a sequence that someone believes appropriate from a logical, instructional, or learning point of view” (p. 15). The National Council of Teachers of Mathematics (NCTM) determined the 108 objectives for third grade mathematics that are used by the 5th and 6th grade teachers of this study. Additionally there are libraries of objectives for each grade level including Common Core libraries. These objectives are administered as diagnostic assessments, consisting of five problems. A score of 80 percent correct indicates achieved mastery to move on to the next objective. This defined list of objectives that show mastery can be assigned to an individual student and accessed to be at their own pace. It does not matter if one student is on the 53rd objective and another student is on the 85th objective. Through out the interviews students, teachers and the administrator saw this ability to implement self-pacing as critical to the students ability to produce tremendous growth in mathematics.

A method of allowing each student to have the amount of time necessary to complete lessons is one of the preconditions necessary to implement mastery learning. This is an important distinguishing feature that is different in the mastery learning classroom than the traditional classroom. When you are teaching in a teacher centered instructional method from a textbook every individual is expect to learn at the pace set by the classroom teacher. Bloom (1968) wrote “Whatever the amount of time allowed by the school and the curriculum for a particular subjects or learning tasks, it is likely to be too much for some students and not enough for other students” (p. 7). The traditional class progresses page-by-page, chapter-by-chapter at a whole classroom pace. In mastery learning students learns at a pace that enables them to master each objective.
A critical aspect of mastery learning is the ability to understand instruction. Bloom (1968) wrote, “The ability to understand instruction may be defined as the ability of the learner to understand the nature of the task he is to learn and the procedures he is to follow in the learning task” (p. 5). No two students will learn at the same rate and in the same way. “Our basic task in education is to find strategies which will take individual differences into consideration but which will do so in such a way as to promote the fullest development of the individual” (Bloom, 1968, p. 3). In the traditional classroom the class is following a textbook and there is generally one way presented to learn an objective. In the 5th and 6th grade classrooms of this case study adjustments were made for the individual students’ learning styles. Lessons could be delivered in interactive computer lessons, video lesson, peer-to-peer oral instruction, small groups with the teacher and one on one with the teacher. These instructional methods led to greater growth in mathematics because the individual differences of students were accommodated.

John B. Carroll (1970) defined perseverance as, “the time the student is willing to spend on active learning” (p. 80). For mastery learning to be effective not only does the school have to allow the student to have the time needed to master a subject, but the student has to actively engage in the learning process. Carroll (1970) wrote:

There is abundant evidence to suggest that perseverance is largely a function of prior experiences of success or failure with similar learning tasks. Often these experiences of success and failure go back to the earliest school years; it must be in these years that it is particularly important to arrange instruction so as to yield experiences of success for all children irrespective of ability (p. 80).
Carroll (1970) goes on to say that students’ successes should be greater than failures, and that prolonged failure will lead students to shutdown and withdraw from engaging in the learning process. Teachers and the administrator of this study reported the importance of adjusting instruction to the individual student so that they can find success in mastering the subject of mathematics. The teachers determined this to be a key factor in the increased student engagement in their classrooms. Differentiating instruction to the individual student’s ability dramatically increased engagement and was significant in producing the positive outcomes on summative math assessments found in the classrooms of this study.

Bloom (1968) expressed that schools were asking the wrong questions about curriculum, materials, and instructional methods in regards to the quality of instruction. All of the questions were based on what was best for a group whether teacher, methods, or materials. Bloom (1968) stated, “One may start with the very different assumption that individual students may need very different types and qualities of instruction to achieve mastery” (p. 4). Carroll (1970) discussed “the important role of ‘formative’ or diagnostic tests, plus the feedback from such tests, in contributing to the quality of instruction (p. 79). The teachers in this rural Alaskan elementary school used a continuous stream of diagnostic assessments with nearly instantaneous feedback that could move a student on to the next learning task, or take the corrective action needed to lead the student to mastery of the objective. Teachers of this study did is what Carroll (1970) described as “The teacher who makes judicious use of such tests and is able to provide encouragement and praise, or corrective feedback as the case may be, is probably a more effective teacher than one who makes only casual or insignificant use of such tests” (p. 79). The effectiveness and the quality of instruction offered by the teachers of this study are made evident by the significant growth their students achieved in their mathematical summative assessments.
Bloom (1968) discussed the affective consequences of mastery learning in his paper Learning for Mastery. The teachers of this study reported perception that a student’s self-concept and engagement in the learning process changes when they find success and begin to believe that they can learn. Bloom (1968) stated, “If the system of formative evaluation (diagnostic progress tests) and the summative evaluation (achievement examinations) informs the student of his mastery of the subject, he [they] will come to believe in his [their] own mastery and competence. The increased student engagement reported by the teachers and administrator is directly related to the student’s change in their self-concept and belief in their ability to master mathematics. Bloom (1968) stated, “When the student has mastered a subject and when he receives both objective and subjective evidence of the mastery, there are profound changes in his view of himself and of the outer world” (p. 11). A student’s academic self-concept of himself or herself is often established in students’ attitude by the end of elementary school. The nature of this self-concept could determine how successful they become students as they move through elementary and middle school, and influence whether they complete high school (Bloom, 1971).

**Discussion of Findings in Relationship to Literature Review**

**The use of technology to differentiate math instruction.** Ysseldyke and Tardrew’s (2007) study was reviewed in Chapter 2 since their study used the same software by Renaissance Learning as the two teachers in the case study. Ysseldyke has been involved in many studies determining the effectiveness of this software to improve math instruction. The study by Ysseldyke and Tardrew (2007) used the STAR Math assessment to measure the grade equivalency growth. Ysseldyke and Tardrew (2007) stated, “Implementation of a progress monitoring and instructional management system had significant and profound positive effects on students in Grades 3 through 6” (p. 24). The 5th and 6th grade teachers’ classes for the 2015-
2016 school year averaged 2.7 years grade equivalency growth. This more than double the 5th grade classes and nearly double the 6th grade classes of Ysseldyke and Tardrew (2007) experimental groups that had “significant and profound positive effects.” The 2.7 years grade equivalency growth of the 5th and 6th grade teachers of this study is below their average over the years. The 6th grade teachers STAR Math growth report is in the appendices showing 6.0 years grade equivalency growth for the 2011-2012 school year.

One reason may be that 5th and 6th grade teachers’ classes of this study made significantly more growth than the classes from Ysseldyke and Tardrew (2007) study is the teachers of this case study only used the diagnostic test portion of Accelerated Math from Renaissance Learning software. The Accelerated Math program assigns practice problems to a student if that student does not demonstrate mastery of a particular math objective. The teachers of this study did not reason that it would be effective to give practice problems related to an objective if that a student has demonstrated a lack of understanding of the objective. The 5th and 6th grade teacher found it more effective to send a student to an interactive computer program that could teach the student the skill necessary to master the objective. Additionally, the 5th and 6th grade teachers of this study could send the student to a video lesson of the objective, have the student work with another student in the class who had mastered the objective, join a teacher led small group of students working on the same objective, or work one-on-one with the teacher.

Liang and Zhou (2009), of the University of Akron conducted a qualitative case study with 55 grade three students in two classrooms to determine how students processed learning mathematics with the use technology and which features of the technology they liked best. The researchers found that the students liked the fact that there was immediate feedback that would correct their misconceptions about mathematics. Students also had the ability to have instruction
repeated and cultivated self-directed learning. The focus groups of students in this study in Alaska had similar reactions, reporting that the immediate feedback was an important feature for them. They also appreciated the ability to have interactive lessons and videos that they could review when necessary.

A mixed-method study was conducted by Rosen and Beck-Hill (2012) to see what impact the use of technology in fourth and fifth grade classrooms in the Dallas, Texas area would have on the outcomes of students’ test scores on the Texas state test using a value added model. This researcher’s case study conducted used a similar method using the Alaska Standards Bases Assessments (SBA) to determine how the use of technology in the 5th and 6th grade teachers’ classrooms impacted the outcomes of their students’ test scores using a value added model. Both the Rosen and Beck-Hill (2012) study and this current study saw significant gains on their state summative assessments. Rosen and Beck-Hill (2012) study also noted that there were fewer discipline problems with their experimental group compared to their control group. Likewise the teachers and administrator from this study reported that the classrooms had few discipline problems, and the environment brought about the increased student engagement with the use of technology.

Valiande and Tarman (2011) conducted a study to find out how technology could be used to differentiate teaching in a mixed ability classroom. They determined that instruction that met the individual needs of the student would be more effective than using the traditional classroom methods of one size fits all. Technology could be used to make the instruction individualized efficiently and effectively. The teachers, administrator, and student focus groups of this study all reported the importance of the self-paced, individualized instructional methods using technology
and believed this is what impacted the student engagement and growth in their understanding of mathematics in the classrooms of this study.

The Use of Technology in Mastery Learning. Miles (2010) conducted a study to determine if a mastery approach to teaching mathematics in 8th grade classes would improve student academic achievement in mathematics. This study was conducted over one semester in the 2006-2007 school year in a southeast Georgia suburban middle school. Prior instructional methods for the group of students utilizing mastery learning methods according to Miles (2010) were “whole-group instruction, teacher led demonstrations, and cooperative learning groups” (p. 70). “The instructional rate was kept at a constant rate based on the GPS timeframe for each instructional unit” (Miles, 2010, p. 70). The treatment group that was using mastery learning differed in that: the instruction was individualized, additional time was allocated, teacher in small groups did remediation, and units were broken down into smaller sections. Miles (2010) treatment group used Accelerated Math diagnostic exams to determine their individual mastery of the Georgia standards. When a student does not master an objective remediation and time is provided in the treatment group. Miles (2010) stated:

Instead of whole group pacing controlled by the teacher with a limited amount of time given for the remediation and mastery of the content, struggling students were given additional time to master the material based on the needs of each student. (p. 73)

At the end of the semester the treatment group and the non-treatment group were given a STAR Math assessment to compare to the STAR Math assessment test given at the beginning of the semester. The treatment group had more than twice the growth of the non-treatment group. Miles’ methods and outcomes are closely related to the outcomes and methods of this study. Miles (2010) does not speak to how additional time was allocated and how additional instruction
was provided. Bloom (1968) referred to this problem as “resources”, or the need for additional people and time. Mastery Learning through numerous research studies over five decades has been established as effective. The 5th and 6th grade teachers of this study have demonstrated the ability to solve the “resource” problem with technology where initial and remedial instruction can be provided through the use of interactive computer lessons that allow each student to have the time they need to master each objective.

Lin, Liu, Chen, Liou, Chang, Wu, and Yuan (2013) conducted a study incorporating mastery learning by building a monopoly game for remedial instruction in upper primary elementary mathematics. They addressed the time and resource issue associated with mastery learning by making the remediation program an after school activity. These researchers of this study found that the activity did increase the achievement of the students who participated. Lin, et al. (2013) “found that an integration of mastery learning strategies with game-based learning provides greater benefits for students learning mathematics” (p. 278). This study did find success in combining mastery learning with technology (Lin et al., 2013).

The impact of technology use on student engagement. Research on student engagement is a relatively new area of study that has yet come to a consensus on theory and definitions (Appleton, Christenson, and Furlong, 2008). Anderman and Patrick (2012) described the relationship between achievement goal theory and student engagement stating, “Achievement goal theory is a framework that is used to explain and study academic motivation classroom” (p. 173). Due to the fact that the classrooms of these two teachers have a mastery goal structure, the relationship between achievement goal theory and student engagement provides insight into what the teachers and administrator reported as increased student engagement. In their classrooms, the teachers in Alderman and Patrick (2012) study “provide supportive instructional discourse, or
scaffolding, compromised of negotiating with students what academic tasks involve and transferring tasks to students in accordance with their capabilities (Turner et al., 2002)” (Anderman & Patrick, 2012, p. 185). They have altered their instructional practices so a “classroom mastery goal structure is established by a coherent set of practices that together communicate a consistent perspective toward learning and task engagement” (Anderman & Patrick, 2012, p. 185) that resulted in a very motivational classroom environment. Anderman and Patrick (2012) believe the convergence and collaboration of goal researchers and engagement researchers will lead to more effective teachers and improved interventions for students. The data gathered from all interviews demonstrate a stronger student engagement due to the mastery goal structure.

**Technology with face-to-face instruction to improve efficiency of math.** Drysdale, Graham, Spring, and Halverson (2012) conducted a meta-analysis of dissertations on blended/hybrid learning. A search was conducted in the ProQuest Dissertation and Theses Database (PQDT) in which they found 205 dissertations that met the criteria for their study. There was little reference to elementary schools in their search. What they lacking in this field is theoretical frameworks and common terminologies (Graham 2013; Drysdale et.al, 2012; Picciano, Dziuban, & Graham, 2014). Definitions vary from Graham (2006) who defined, “blended learning systems combine face-to-face instruction with computer-mediate instruction” (pg.6) to Staker and Horn (2012) who defined blended learning as:

A formal education program in which a student learns at least in part through online delivery of content and instruction with some element of student control over time, place, path, and/or pace and at least in part at a supervised brick-and-mortar location away from home; and the modalities along each student’s learning path within a course or subject are
connected to provide an integrated learning experience. (p. 290)

The students in this study are in a self-contained classroom that can control the pace of their learning, however they cannot control the time or place. Staker and Horn (2012) sought to define the various strategies of blended learning instruction finding four that were common in their study. The four common methods found are: station rotation, lab rotation, flipped classroom, and individual rotation. The students and 5th and 6th grade teachers of this study use what Staker and Horn (2012) described as individual rotation. Students in the 5th and 6th grade classroom went to computers based on the individual needs of the student. While students can and do access their work from home the classroom in many ways resembles a traditional 9:00 AM to 3:30 PM classroom.

**Mastery learning.** Block and Robert B. Burns (1976) collected what they believed to be the best mastery learning studies from the 1968 through 1976. They examined four aspects of mastery learning the: quantitative aspects, the affective aspects, different styles of learners, and why does mastery works and how to implement it.

The first aspect was the quantitative aspect. Block and Burns (1976) concluded that mastery learning produced greater student learning. This case study shows that the student learning in the 5th and 6th grade classroom of this small Alaskan school was quantitatively significantly greater that the other 5th and 6th grades that their growth was compared too.

The second aspect Block and Burns (1976) examined was the affective consequences of mastery learning. They describe this as, “academic self-confidence, attitudes toward cooperative learning, and attitudes toward instruction” (Block & Burns, 1976, p. 26). Block and Burns concluded affective consequence looked favorable for mastery learning but thought that more studies needed to be conducted in this area of mastery learning. As reported by the teachers and
The method of instruction used in the 5th and 6th grade classrooms of this study impacted student’s self concept and student engagement in class activities. Block and Burns (1976) noted that the slower learners time needed to reach mastery began to improve and the gap between time needed for fast learners and slower learners decreased. In this case study in a rural Alaskan school the 5th and 6th grade classrooms growth represented multiple grade year equivalency. Assuming that the growth expectancy for average students is one year per school year and noting that the time needed to reach mastery of an objective decreased significantly for students in this Alaskan case study. The impact of mastery learning in a highly differentiated blended learning environment decreased the time required for mastery for both average and below average students.

The third aspect that Block and Burns (1976) was to examine the effectiveness of mastery learning with different kinds of learners. Block and Burns (1976) concluded “we would hypothesize that the reason the unit mastery requirement and the meeting of that requirement have exerted such an influence over student learning is because they have affected the quality and the quantity of student study time” (p. 35-36). While the data collected from this case study does not disagree with these findings, the teachers of this case study took a different approach to different learning styles. Students could select a learning method that was more impactful for them. Students could use interactive computer programs that would accommodate many styles of learning. Additionally, students could choose to address a visual-spatial learning style. Students could work with a peer or teacher to address a verbal-linguistic style. Teachers in this study were pragmatic in their different approaches to instruction, thus allowing students to learn an objective using the method that was most effective for the individual student.
The fourth aspect that Block and Burns (1976) examine was why mastery learning works and how to implement it. Block and Burns concluded that teachers learning to implement mastery learning did not have to develop an entire new set of skills but be required:

a few new skills (e.g., diagnostic testing skills) to an existing repertoire (e.g., the use of remedial instruction) and the orchestration of these new skills with the old (e.g., learning how to use diagnostic test results to guide the choice of remedial learning activities).

(p. 38)

The teachers in this study achieved significant student growth in mathematics by utilizing formative diagnostic tests and responding to the outcomes of those individual student tests by assigning remedial instruction targeted to the individual student with the use of technology.

Thomas R. Guskey and Sally L. Gates (1986) picked up where Block and Burns (1976) left off searching for mastery learning studies from 1976 to 1986. Their initial search found 234 potential that was reduced to 27 that met the criteria to be included. This study concluded that 25 of the elementary and secondary schools “showed positive effects as a result of the application of group based mastery learning strategies” (Guskey & Gates, 1986, p. 74). The key here is these were “group based mastery learning strategies.” The teachers of this case study have broken down mastery learning to the individual student that resulted with considerably greater growth than the schools in this study. The Guskey and Gates (1986) study concluded that mastery learning did increase the rate of learning for slower students, which would coincide with the results found in the Alaskan study, however, it also increased the rate of learning for the faster students. The Guskey and Gates (1986) study also looked at retention of learned material was greater in the experimental groups than the control groups. While the study in Alaska did
not investigate retention the results on summative assessments for the classrooms would indicate that retained the material taught.

The meta-analysis conducted by Chen-Lin C. Kulik, James A. Kulik, and Robert L. Bangert-Drowns (1990) examined the effectiveness of mastery learning in 108 studies from their search in the Educational Resources Information Center (ERIC), Comprehensive Dissertation Abstracts and original article retrieved from the databases. Positive results were reported in 96 of the studies examined. Of the 96 studies reporting positive outcome only 67 were what (Kulik et al., 1990) described as significant. Of these 96 studies eight were conducted in elementary schools. In the eleven studies that did a follow up assessment for retention all eleven demonstrated a positive effect. In the studies that addressed the variable of attitude toward instruction, 16 of 18 students showed a more positive attitude. In the studies that addressed the variable of attitude toward subject matter, 12 of 14 found a more positive attitude toward subject manner. These results coincide with what was reported by teachers and students in this case study in regards to engagement and self-concept increasing in a positive manner. The Kulik et al. (1990) study concluded that the affect of mastery learning was more significant for weaker students. The data from this case study notes the impact of mastery learning as it works equally well for all students contrary to the conclusion of Kulik et al. (1990).

**Conclusions**

The practical goal of this study was to determine how the use of a blended learning environment with highly differentiate instruction in the two classrooms of a rural Alaskan 5th and 6th grade classrooms significantly increased the outcomes on their classrooms math summative assessments. The intellectual goals to be considered were:
1. To investigate how the instructors of this new design perceive the design as having a significant impact on student learning, mastery, and engagement.

2. To identify what methods of math instruction increased the standardized test scores at Herbert Hoover Elementary School as perceived by teachers, administrators and students.

These goals were based on the research question for this study:

1. How has the development of a blended learning classroom with a focus on mastery learning greatly impacted mathematics achievement in an elementary school, as perceived by three teachers using the program, the administrator, and students?

To answer this question interviews were conducted with the administrator of the school, the 5th and 6th grade teachers and student focus groups from these classrooms. The data from these interviews was coded and then an analysis of the themes that developed from the coding was studied.

The study showed that the teachers had developed a form of mastery learning that, through technology, allowed individualized instruction for every student. The teachers had solved two problems of mastery learning: additional time needed by the student and remedial instruction needed by students to achieve mastery of the subject. Bloom (1968) stated, “Tutorial help (one to one relations between teacher and learner) represents the most costly type of help and should be used only where alternative procedures are not effective” (p. 5). The teachers of this study used interactive computer lessons and videos to replace the tutorial help needed, making this instructional method cost feasible. Using the Renaissance Learning Accelerated Math objectives to determine mastery of the subject solved the time needed by the individual students. Students could proceed through the objectives at their own pace which students
reported to be an important piece of why their growth in mathematics was significant. These teachers dramatically reduced the time of whole class instruction and began individualized instruction meeting the individual students needs with the use of technology. Bloom (1968) addressed the affective consequences of mastery learning with one impact being a positive impact on the students’ self-concept. Both teachers reported that, as students found success by having instructional level adjusted to the individual student’s, the student’s resultant engagement in the learning process increased due. Teachers felt that students began to believe they could master the subject of mathematics. Using the methods of instruction used by the 5th and 6th grade teachers in this study, classes have consistently observed the type of growth presented in this study since 2005-2006 school year.

**Limitations**

The most significant limitation of this study is the size of the study. Only two classrooms in a rural Alaskan school were considered. Additional research would be needed to verify the reliability of the instructional methods of these two teachers and to examine if their method of instruction is transferable to other classrooms with similar outcomes. While there are studies that use technology in the classroom, many with the Renaissance software used by the teachers of this study, there were no studies that used this software for only diagnostic purposes. There is a lack of prior research studies that uses technology for diagnostics in combination with using technology to provide the “knowledgeable other” to teach students objective. This lack of prior research that matches the methods of instruction used in this case study places obstacles in building a solid foundation of prior studies in the literature review. The demographic makeup of this school limits the ability of this study to make generalizations that could be applied in the
lower 48 state of the United States due to the large Alaska Native population in the rural Alaskan elementary school.

**Significance and Possible Implications of Study**

The growth rate in mathematics that the teachers of this study recorded on summative assessments is significantly greater than what the researcher could find in other studies. The concepts of individualized student centered instruction are widely acknowledged by many studies. However none of these studies demonstrate the multi grade level equivalency growth that has consistently occurred in the two classrooms of this case for now over a decade. This method of instruction could be what is known as a disruptor, and over time could change the instructional methods in future classrooms. When classrooms can progress at multiple grade levels in a single school year consistently for over a decade this a method that should be utilized in schools everywhere. There has been multiple math curriculums come through this Alaskan Elementary School of which none have made a significant difference in outcomes. The instructional methods used by the 5th grade and 6th teachers of this school have consistently had greater growth on the Alaska Standards Based Assessments than the other intermediate teachers in the school district. Now that Alaska does not have a state tests this school has utilized the MAP test by NWEA and the Renaissance Learning STAR Math test to measure growth. Both assessments are used by millions of students internationally. The outcomes on last year’s assessments were consistent with the outcomes they gotten for multiple years.

The 6th Grade teacher’2015-2016 class average showed 2.7 years grade equivalency growth on their STAR Math Growth Report and was in the 97 percentile in their School Conditional Growth Percentile on the MAP assessment of NWEA (over 10 million students in this norm referenced test) for the 2015-2016 school year. The class began the year with a class
average RIT score of 219, which is two points above the norm for a beginning 6th grade class. The RIT score average for the 6th grade teacher’s class on their spring MAP test was 233.1. The norm for a beginning 11th grade class is 233.3 (Appendix D). This class had statistically significant growth in mathematics for the 2015-2016 school. The 6th grade teacher has consistently gotten this kind of growth in mathematics from her students over many years. The 2.7 years growth is on the low side of her usual STAR Math growth report as can be witnessed by her 2011-2012-class STAR Math growth report with 6.0-grade equivalency growth (Appendix C).

The Mark O’Brien’s 2015-2016 class average showed 2.7 years grade equivalency growth on their STAR Math Growth Report and were in the 99 percentile in their School Conditional Growth Percentile on the MAP assessment of NWEA (over 10 million students in this norm referenced test) for the 2015-2016 school year. His class began at about a 4.3 grade equivalency based on the MAP norms and ended with a approximately a 6.9 grade equivalency based on MAP norms (Appendix D). This outcome on MAP aligns with the outcome on his Math growth report. The 5th grade teacher has consistently gotten this type of outcomes for the last 10 years using mastery learning in blended learning form of instruction. This student growth is statistically significant compared to most forms of instruction.

**Future Studies**

Through the data collected in this study the participants reported the importance of instruction being differentiated to the academic needs of individual students. Future studies will need to provide evidence that differentiated instruction is based on empirical evidence that is researched based. While there exists a significant amount of research on mastery learning there is a lack of research where technology is used to differentiate mastery learning to the individual
student. Drysdale et.al. (2012) found very few studies conducted to examine blended learning environment with using a combination of face-to-face instruction and computer-mediate instruction. This is an area that needs considerable increase in studies to examine the possibilities of using technology effectively in the classroom.

Differentiated instruction has been the topic of numerous books and articles and there is a sempiternal amount of information on differentiated instruction on the internet. What many reviews of the literature have noted is that there is a lack of evidence proving that differentiated instruction is effective. Tracey Hall, Nicole Strangman, and Anne Meyer (2003) in a paper for the National Center on Accessing the General Curriculum (NCAC) wrote, “Based on this review of the literature of differentiated instruction, the ‘package’ itself is lacking empirical validation” (p. 5). This sentiment has been restated by many other studies and reviews including Pearl Subban (2006) and Brenda Logan (2011). Future studies will need to investigate what is the proper balance of instructional level, time on task, and motivation to produce the ideal environment for increasing the accessed growth rate of the individual skills and content mastery. There are many elements of differentiated instruction and to date research has chosen to examine individual aspects of this method rather than developing studies that examine the whole picture of differentiated instruction.

Assuming that differentiated theory is based mainly on Vygotsky’s (1978) sociocultural theory (Valiande et al., 2011) studies will need to be designed that can examine the continual cyclical movement of students going from ZPD to ZAD repeatedly ad infinitum. Within the current constricts of public schools where the average pupil to teacher ratio is 20 to 1 (Synder and Dillow, 2011) research will be needed to examine the most efficient manner to differentiate instruction using today’s technology. This would be necessary because as differentiation applies
to the individual student, the teacher would not have sufficient time to be the “knowledgeable other” for all students. Research on how technology could be used to instruct students who are in their ZPD is paramount if differentiated instruction is to be used extensively in public schools. To enable teachers to address individual student needs without technological assistance teacher to pupil ratios will have to be drastically reduced, making full differentiation cost feasible to implement. Research should be conducted determining an optimal age range or content area where computers acting as the “knowledgeable other” will be effective. This would include studies of the capabilities of computers to become substitutes for human tutors.

**Personal Reflection**

The researcher in this study began using the methods used by the 5th and 6th grade teacher when he came to the school of this case study in 2005. The researcher’s first class consisted of 17 Title I students and five ESL students. The abilities of the students were wide ranging with many gaps in their mathematics understanding. The researcher purchased eight Dell desktop computers and began individualizing the students’ math instruction due to the fact he did not see whole class instruction as an effective means of meeting the individual needs of the students. Using Accelerated Math diagnostics tests (5 questions on each test) to determine the individual student’s understanding of the math objectives that a student should have mastered to meet the state standards expectations. When a student demonstrated lack of mastery on an objective they were sent first to an interactive computer lesson on the objective. If this did not work the student would work with a peer who had demonstrated mastery of the objective to learn the skill needed to master the objective. If this method was not successful then the teacher would work with the student one-on-one.
In the 2013-2014 school year the researcher became the assistant principal and implemented the Measure of Academic test (MAP) from Northwest Evaluation Association to use as a measuring tool to measure academic growth. The state test was changing to the Common Core standards and it would take a few years to get a baseline to measure growth. The new test developer was terminated after the 2014-2015 school year and Alaska did not take a standardized test in the 2015-2016 school year. Alaska has yet to hire a vendor to create and implement a test for the 2016-2017 school year as of November 2016, hence the MAP was viewed as a necessity by the researcher to measure student growth. The researcher became the principal in the 2014-2015 school year and took the methods of instruction used in the 5th and 6th grade teachers of this study building wide. The technology in the building was sufficient to begin this change in instructional methods. The researcher spent a few hours in each classroom to help teachers begin moving from teacher centered instruction to individualized instruction using Mastery Learning theory in a blended environment. To begin the process teachers implemented a STAR Math test to determine where each student should begins in the Accelerated Math libraries. Formative assessments are assigned to students and the process of determining what each student understands and does not begins. When a student does not demonstrate mastery of a formative assessment the teacher must decide what is the most efficient way for this student to learn the objective. There are many options to choose from ranging from an interactive computer lesson, Kahn Academy assignment, peer-to-peer help or one-on-one with the teacher. When the teacher decides the student has learned the objective the student will attempt to demonstrate mastery of the objective again.

The average for students meeting their projected growth on the MAP test from first grade through sixth grade was 134 percent in the first year. The expectation of projected growth on the
MAP test is 50 percent. Dr. Nate Jensen (2013) from NWEA stated “if a school or district only has 50% of students meeting or exceeding their growth projections, this shouldn’t be viewed as poor performance – instead, this should be viewed as the students in a school or district showing growth consistent with what we would likely expect to observe” (“Interpreting Growth Projections,” para. 5). The researcher saw many teachers overwhelmed by the increased student engagement that these methods of instruction creates, as they switched from teacher-centered instruction to student-centered instruction. This study demonstrates that Bloom (1968) was correct and that school’s need to avoid the “educational trap” of viewing students, instructional materials, curriculum, and teachers as groups. The use of technology allows students the ability to learn content at their own pace and at the appropriate level of instruction, which gives the student the opportunity to “master” subject content. School must begin viewing students as individuals with individual needs. The teachers in this study taught students as individuals rather than a group and greatly increased the effectiveness and assessed academic growth of their classrooms.
References

*The Theory and Practice of Online Learning* (pp. 15-44). Edmonton, Canada: AU Press, Athabasca University.

Learning to value mathematics and reading: relations to mastery and performance-oriented instructional practices. *Contemporary Educational Psychology, 26,* 76-95.
doi: 10.1006/ceps.1999.1043


Bloom, R. M. (2010). Implementation practices of differentiated instruction in the upper elementary and middle school classroom: a discovery through grounded theory (Doctoral dissertation) Retrieved from ProQuest (UMI 3396747)


Whalen, C., Kowalewski, K., & Arnold, R., The economic outlook (2011). In Bogusz, C., Kelly, K., Mazade, L., Skeen, J., & Snyder, S (Eds.), *The Budget and economic outlook: Fiscal*
Appendix A

Teacher Interview Protocol

INTRODUCTION

Introductory Protocol

Thank you for your willingness to participate in this study. The reason I have selected you to participate in this study is due to the fact that on all summative assessments over the past decade you have consistently been among the few elementary intermediate teachers with the greatest amount of student growth. You have showed significantly greater student growth than 95% percent of the other elementary intermediate teachers in this district on SBA assessments, STAR Math Assessments and MAP assessments. Through this study we hope to find how you have consistently managed to do so every school year. We hope to examine what strategies and instructional methods you have used to accomplish this and determine if these methods are transferrable to other educators.

Due to the fact that your responses are important to this study I would like to digitally record our conversation. I will take notes, however the recording will ensure that I do not miss any information on how from your perspective you manage to consistently get tremendous growth from your students. The digital recordings will be transcribed and then deleted. I will be the only one with access to the transcriptions which be kept in a safe in my home. All information will be kept confidential and a pseudonym will be used to label the tapes and pseudonym will be used for you in the study.

It is the policy of Northeastern University that no activity involving human subjects be undertaken until those activities have been reviewed and approved by the University’s Institutional Review Board (IRB). All university research involving human subjects must first be reviewed by the Office of Human Subject Research Protection to ensure that this study is in compliance with federal, state and the university’s statutes and regulations relating to the protection of human subjects. To begin this interview you will need to sign a consent document that states: (1) All data gathered in this study will be kept completely confidential, publication will use pseudonyms for all participants as well as location of study will use pseudonyms, (2) your participation is voluntary and you can opt out at anytime, and (3) we do not intend to inflict any harm. If you have questions about this form or the interview process please ask. I would also like to digitally record this session and I have a document for you to sign giving us permission to do so. This recording will be deleted after it has been transcribed.

This session is one hour and I have many questions that I would like you to respond to. If there is need to pick up the pace to ensure that we get through all the questions I will let you know. Do you have any questions before we start?
Introduction to Interview I

Interviewee Background – My name is David L. Jones and I am a doctoral student at Northeastern University. I am currently working on my thesis to finish my doctoral studies. I am the principal at Houghtaling Elementary School. I have been the administrator for three years and was a classroom teacher for eight years prior to becoming the principal at Houghtaling Elementary School. I have been in the education profession for 16 years.

Background Info

1. First, just a little background information. Can you tell me about your background as an educator and how it is that you came into the field of education?

2. The focus of this study (and thus interview) is primarily about the blended classroom environment you used from 2008 until 2016 to teach mathematics. How is that you came to teach math in this way during 2008 through 2016? [Capture the story.]

Instructional Methods

3. So, as I said before, I am primarily interested in the math program that you/we taught during [2008 through 2016] How would you describe teaching math in this way … and how does it differ from the way you used to teach math? [Ask for specific details, differences with LOTS of EXAMPLES]
   - How do you think it impacts students’ engagement in learning math?
   - How do you think students learn math different in this class from typical classrooms?
     [EXAMPLES]
   - What is the role of technology?
   - What is the role of the teacher, and how is that different from what you consider to be more typical of classroom instruction?
   - What do you think are the benefits of teaching math in this way?
     - Can you illustrate that in terms of talking about specific students and how learning math in this way benefited them?
     - Is there anything that might not work as well for some students? What ways? Why do you think that is? [Ask for specific examples with specific students]

4. In this classroom, how do all students master the objectives you present to them in your lessons?

5. How did/does your instructional methods in this classroom accommodate faster learners and slower learners?

6. How did/does your instructional methods accommodate for different kinds of learning styles, e. g., oral learners and visual learners

7. How do you determine if a student has learned the objective of a lesson?
8. How important is tracking every student’s progress and how do you go about that task in this classroom?

9. In this classroom, how do you think instructional is differentiated for each student? And how does that benefit your students and their learning? [SPECIFIC EXAMPLES referring to STUDENTS]

10. How did learning how to teach in this way change your perspective about teaching and learning and your own perception of you as a teacher?

11. In the end, it has been found that student growth in math was much greater in this classroom than other math classrooms. What do you attribute to this outcome?

12. Finally, how do you think this method of teaching and learning could benefit other students and teachers?
Appendix B

Student Focus Group Interview Protocol

INTRODUCTION

Introductory Protocol

Hi. My name is David Jones and I used to teach in this school three years ago and I am now the principal. Before we begin we will discuss talk about confidentiality of today’s discussion. These conversations are private and not to be shared outside of this room.

Today I will be asking you questions that there are no right answers or wrong answers. I realize everyone’s perspective could be different and that is fine and to be expected. I am only interested in everyone’s personal perspective. At anytime if you are uncomfortable or feel anxious by the questions you may leave and it will not be held against you in any way. Your participation is completely voluntary.

I am looking at how math was taught to you in 5th/6th grade and would like to ask you today about your thoughts, feelings, and experiences learning math in 5th/6th grade.

Because what you have to say is so important to me, I am going to record it so that I can listen back to what you said.

I really appreciate you helping me think about this.

Do you feel ok participating and helping me by answering some questions?

One VERY important thing. I want you to answer me honestly. No answer is right or wrong. I just want to know what you really think. Ok?

Focus Group Interview

1. Tell me how you learned math in this class?
   - Can you give me some specific examples? [Probe for a lot of specifics. Details. Examples.]
   - How is that different from how you learned math in the past and/or learning math now? [Can you give me an example of that. Get a lot of these.]

2. Do you feel that the use of technology helped you learn math better in this class?
   - If so, how so? If not, how not? [Examples.]

3. How did the teacher help you learn math in this classroom?
- Was that helpful? How so? Not helpful? Now not?

4. Do you feel having math objectives specifically for you helped you to learn math better? How so? How not?

5. How did you feel about everyone in the classroom working on different math objectives everyday in this class?

6. Do you feel the way you were able to work with other students and your teacher helped you to learn math? How so?
   - Did it help you when you were struggling learning something? And, if so, how so?
   - How is this different from how you learn math in other classes?

7. Do you feel you could learn math better in this class? Why do you say that? How did it make you a better math learner?

8. Would you recommend that other students learn math in this way? Why do you say that?
Appendix C

Growth Report
Printed Friday, March 09, 2012 1:21:05PM

School: Houghtaling Elementary School
Pretest Dates: 8/31/2011 - 6/2/2012
Posttest Dates: 8/31/2011 - 6/2/2012

Class: Reynolds - ER6

Growth Summary

<table>
<thead>
<tr>
<th></th>
<th>GP</th>
<th>SS</th>
<th>GE</th>
<th>PR</th>
<th>NCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest Mean</td>
<td>6.02</td>
<td>737</td>
<td>6.2</td>
<td>57</td>
<td>53.7</td>
</tr>
<tr>
<td>Posttest Mean</td>
<td>6.60</td>
<td>845</td>
<td>12.2</td>
<td>82</td>
<td>69.4</td>
</tr>
<tr>
<td>Change</td>
<td>+0.58</td>
<td>+108</td>
<td>+6.0</td>
<td>+25</td>
<td>+15.7</td>
</tr>
</tbody>
</table>

Number of Students: 23
Appendix D

<table>
<thead>
<tr>
<th>Fall 2015 5th Grade</th>
<th>Spring 2016 5th Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary</td>
<td>Summary</td>
</tr>
<tr>
<td>Total Students With Valid Growth Test Scores</td>
<td>15</td>
</tr>
<tr>
<td>Mean RIT</td>
<td>205.5</td>
</tr>
<tr>
<td>Median RIT</td>
<td>206</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>16</td>
</tr>
<tr>
<td>Norm Grade Level Mean RIT</td>
<td>211.4</td>
</tr>
<tr>
<td>Students At or Above Grade Level Mean RIT</td>
<td>4</td>
</tr>
<tr>
<td>Total Students With Valid Growth Test Scores</td>
<td>22</td>
</tr>
<tr>
<td>Mean RIT</td>
<td>225.5</td>
</tr>
<tr>
<td>Median RIT</td>
<td>226.5</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>16.3</td>
</tr>
<tr>
<td>Norm Grade Level Mean RIT</td>
<td>221.4</td>
</tr>
<tr>
<td>Students At or Above Grade Level Mean RIT</td>
<td>14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fall 2015 6th Grade</th>
<th>Spring 2016 5th Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary</td>
<td>Summary</td>
</tr>
<tr>
<td>Total Students With Valid Growth Test Scores</td>
<td>25</td>
</tr>
<tr>
<td>Mean RIT</td>
<td>219.2</td>
</tr>
<tr>
<td>Median RIT</td>
<td>222</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>13.4</td>
</tr>
<tr>
<td>Norm Grade Level Mean RIT</td>
<td>217.6</td>
</tr>
<tr>
<td>Students At or Above Grade Level Mean RIT</td>
<td>15</td>
</tr>
<tr>
<td>Total Students With Valid Growth Test Scores</td>
<td>24</td>
</tr>
<tr>
<td>Mean RIT</td>
<td>233.1</td>
</tr>
<tr>
<td>Median RIT</td>
<td>237</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>12.1</td>
</tr>
<tr>
<td>Norm Grade Level Mean RIT</td>
<td>225.3</td>
</tr>
<tr>
<td>Students At or Above Grade Level Mean RIT</td>
<td>18</td>
</tr>
</tbody>
</table>

NWEA MAP Norms

<table>
<thead>
<tr>
<th>2015 MATHEMATICS Student Status Norms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begin-Year</td>
</tr>
<tr>
<td>Grade</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>K</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
</tbody>
</table>
Appendix F

5th Grade Accelerated Math Common Core Library

Topic 1 - Number and Operations in Base Ten: Operations Multi-digit Whole Number
Obj. 1 - Multiply a 3-digit whole number by a 2-digit whole number
Obj. 2 - Find the product of three identical factors
Obj. 3 - Multiply three 1- and 2-digit whole numbers
Obj. 4 - Multiply a 3- or 4-digit whole number by a 3-digit whole number
Obj. 5 - Divide a 3- or 4-digit whole number by a 2-digit whole number, with no remainder and no zeros in the quotient
Obj. 6 - Divide a 3- or 4-digit whole number by a 2-digit whole number, with a remainder and no zeros in the quotient
Obj. 7 - Divide a 3- or 4-digit whole number by a 2-digit whole number, with no remainder and at least one zero in the quotient
Obj. 8 - Divide a 3- or 4-digit whole number by a 2-digit whole number, with a remainder and at least one zero in the quotient
Obj. 9 - Divide a 3- or 4-digit whole number by a 2-digit whole number and express the quotient as a mixed number
Obj. 10 - WP: Divide a whole number of up to 4-digits by a 2-digit whole number, with no remainder
Obj. 11 - WP: Divide a whole number of up to 4-digits by a 2-digit whole number and interpret the remainder

Topic 2 - Number and Operations in Base Ten: Decimals
Obj. 12 - Determine the decimal number through thousandths when given its word form
Obj. 13 - Determine the decimal number through thousandths when given its expanded form
Obj. 14 - Determine the decimal number through thousandths represented in expanded form using powers of ten
Obj. 15 - Determine the word form of a decimal number through thousandths
Obj. 16 - Compare two decimal numbers through thousandths represented in expanded form
Obj. 17 - Compare two decimal numbers through thousandths
Obj. 18 - Round a decimal number to a specified place through hundredths
Obj. 19 - Add two decimal numbers through hundredths using pictures
Obj. 20 - Add two decimal numbers through hundredths using a place value chart
Obj. 21 - Add two decimal numbers through hundredths
Obj. 22 - Add three decimal numbers through hundredths using strategies based on properties of operations
Obj. 23 - Subtract decimal numbers through hundredths using pictures
Obj. 24 - Subtract decimal numbers through hundredths using a place value chart
Obj. 25 - Subtract decimal numbers through hundredths
Obj. 26 - Relate multiplication of a decimal number through tenths by a whole number to a model
Obj. 27 - Relate multiplication of a decimal number through tenths by a decimal number through tenths to a model
Obj. 28 - Multiply a decimal number through hundredths by 10, 100, or 1,000
Obj. 29 - Multiply a decimal number through hundredths by a 1-digit whole number
Obj. 30 - Multiply a decimal number through hundredths by a 2-digit whole number
Obj. 31 - Multiply a decimal number through hundredths by a decimal number through tenth
Obj. 32 - Relate division of a whole number by a decimal number through tenths to a model
Obj. 33 - Relate division of a decimal number through tenths to a model
Obj. 34 - Divide a decimal number by 10 or 100
Obj. 35 - Divide a whole number or a decimal number by 0.1 or 0.01
Obj. 36 - Divide a 1-digit whole number by a decimal number through hundredths where the quotient is a whole number
Obj. 37 - Divide a 2- to 3-digit whole number by a decimal number through hundredths where the quotient is a whole number
Obj. 38 - Divide a decimal number through hundredths by a 1-digit whole number
Obj. 39 - Divide a decimal number through hundredths by a decimal number through hundredths

**Topic 3 - Operations and Algebraic Thinking**
Obj. 40 - Evaluate a numerical expression of two operations with parentheses, using order of operations
Obj. 41 - Evaluate a numerical expression of three operations with parentheses, using order of operations
Obj. 42 - Evaluate a numerical expression of four or more operations with parentheses, using order of operations
Obj. 43 - Translate a verbal expression into a numerical expression
Obj. 44 - Translate a numerical expression into a verbal expression
Obj. 45 - Represent powers of 10 using whole-number exponents
Obj. 46 - WP: Generate two numerical patterns using two given rules
Obj. 47 - WP: Determine the relationship between corresponding terms in a table containing two different numerical patterns

**Topic 4 - Number and Operations: Fractions**
Obj. 48 - Add fractions with unlike denominators that have factors in common
Obj. 49 - Add fractions with unlike denominators that have factors in common and simplify the sum
Obj. 50 - Add fractions with unlike denominators that have no factors in common
Obj. 51 - Subtract fractions with unlike denominators that have factors in common
Obj. 52 - Subtract fractions with unlike denominators that have factors in common and simplify the difference
Obj. 53 - Subtract fractions with unlike denominators that have no factors in common
Obj. 54 - Add mixed numbers with unlike denominators and simplify the sum
Obj. 55 - Subtract mixed numbers with unlike denominators and simplify the difference
Obj. 56 - Add two mixed numbers with unlike denominators or a mixed number to a fraction with unlike denominators and simplify the sum
Obj. 57 - Subtract two mixed numbers with unlike denominators or subtract a fraction from a mixed number with unlike denominators and simplify the difference
Obj. 58 - Estimate a sum of two fractions using benchmark numbers 0, 1/2, and 1
Obj. 59 - Estimate a difference of two fractions using benchmark numbers 0, 1/2, and 1
Obj. 60 - WP: Add or subtract fractions with unlike denominators that have no factors in common
Obj. 61 - WP: Add or subtract mixed numbers with unlike denominators that have no factors in common
Obj. 62 - WP: Estimate a fraction sum or difference using benchmark numbers 0, 1/2, and 1.
Obj. 63 - WP: Add or subtract fractions with unlike denominators and simplify the sum or difference
Obj. 64 - WP: Add or subtract mixed numbers with unlike denominators or a mixed number and a fraction with unlike denominators and simplify the sum or difference
Obj. 65 - Relate a fraction to a division sentence
Obj. 66 - WP: Divide whole numbers resulting in a fraction or mixed number
Obj. 67 - Relate the product of a fraction and a whole number to a model
Obj. 68 - Relate the multiplication of a fraction by a whole number to an equivalent expression
Obj. 69 - Relate the multiplication of two fractions to an equivalent expression
Obj. 70 - Relate the product of two fractions to a rectangular area model
Obj. 71 - Determine the area of a rectangle with fractional side lengths by tiling
Obj. 72 - Multiply a fraction by a fraction
Obj. 73 - Multiply a mixed number by a whole number
Obj. 74 - Multiply a mixed number by a fraction
Obj. 75 - Multiply a mixed number by a mixed number
Obj. 76 - Determine the area of a rectangle with fractional side lengths using multiplication
Obj. 77 - Determine the result of multiplying a number by a fraction equal to 1, less than 1, or greater than 1
Obj. 78 - WP: Multiply two fractions
Obj. 79 - WP: Multiply two mixed numbers or a mixed number and a fraction
Obj. 80 - Relate a situation involving division of a unit fraction by a non-zero whole number to a numeric expression
Obj. 81 - Divide a unit fraction by a non-zero whole number
Obj. 82 - Relate a situation involving division of a whole number by a unit fraction to a numeric expression
Obj. 83 - Divide a whole number by a unit fraction using a model
Obj. 84 - Divide a whole number by a unit fraction
Obj. 85 - WP: Divide a unit fraction by a non-zero whole number
Obj. 86 - WP: Divide a whole number by a unit fraction

**Topic 5 - Measurement and Data**

Obj. 87 - Solve a problem with fractions involving any of the four operations by using information presented in a line plot with a fractional scale to eighths
Obj. 88 - Convert between customary units of length using fractional amounts
Obj. 89 - Convert between customary units of capacity using fractional amounts
Obj. 90 - Convert between customary units of weight using fractional amounts
Obj. 91 - Convert between metric units of capacity using decimal amounts
Obj. 92 - Convert between metric units of mass using decimal amounts
Obj. 93 - Convert between metric units of linear measurements using decimal amounts
Obj. 94 - WP: Solve a multi-step real-world problem involving unit conversions within the customary system
Obj. 95 - WP: Solve a multi-step real-world problem involving unit conversions within the metric system

**Topic 6 - Geometry: Concepts and Measurement**

Obj. 96 - Determine the location of an ordered pair in the first quadrant
Obj. 97 - Determine the location of an ordered pair in the first quadrant using compass directions
Obj. 98 - Determine how to travel from the origin to a given point in the first quadrant
Obj. 99 - Determine the ordered pair of a point in the first quadrant
Obj. 100 - WP: Graph a point in the first quadrant of the coordinate plane to represent a problem
Obj. 101 - Classify a 2-dimensional figure into categories and subcategories based on attributes
Obj. 102 - Determine the volume of a right rectangular prism by counting unit cubes
Obj. 103 - Determine the volume of a right rectangular prism given a diagram
Obj. 104 - Determine the volume of a right rectangular prism
Obj. 105 - WP: Determine the volume of a right rectangular prism given a diagram and formula
Obj. 106 - WP: Determine the volume of a right rectangular prism given a formula
Obj. 107 - Determine the volume of a solid figure composed of right rectangular prisms by decomposing it into two non-overlapping parts and adding the volumes of the non-overlapping parts
Obj. 108 - WP: Determine the volume of a solid figure composed of right rectangular prisms by decomposing it into two non-overlapping parts and adding the volumes of the non-overlapping parts

6th Grade Accelerated Math Common Core Library

**Topic 1 - Ratios and Proportional Relationships**

Obj. 1 - Relate a ratio to a diagram
Obj. 2 - WP: Determine a ratio using whole numbers less than 50
Obj. 3 - WP: Determine the ratio of two whole numbers, at least one of which is larger than 50
Obj. 4 - Determine a ratio relationship between two quantities
Obj. 5 - Determine a unit rate
Obj. 6 - Relate an input-output table to equivalent ratios
Obj. 7 - Find a missing value in a ratio table
Obj. 8 - Determine the graph of the values in a ratio table
Obj. 9 - WP: Compare two ratios using tables
Obj. 10 - WP: Determine a unit rate with a whole number value
Obj. 11 - WP: Determine a unit rate with a decimal value
Obj. 12 - WP: Use a unit rate with a whole number or whole cent value to solve a problem
Obj. 13 - Relate a percent of a quantity to a rate per 100
Obj. 14 - WP: Determine a percent where a ratio, not in 100ths, is given
Obj. 15 - WP: Relate a percent of a quantity to a rate per 100
Obj. 16 - Determine the percent less than 100% given a part and a whole
Obj. 17 - Determine the part given a whole and a percent less than 100%
Obj. 18 - Determine the whole given a part and a percent less than 100%
Obj. 19 - Determine the part given a whole and a percent more than 100%
Obj. 20 - Determine the whole given a part and a percent more than 100%
Obj. 21 - WP: Determine the percent less than 100% given a part and a whole
Obj. 22 - WP: Determine the part given a whole and a percent less than 100%
Obj. 23 - WP: Determine the whole given a part and a percent less than 100%
Obj. 24 - WP: Determine the percent less than 100% given two parts of a whole
Obj. 25 - WP: Determine the whole given a part and a percent more than 100%
Obj. 26 - Convert measurement units using ratios
Obj. 27 - WP: Solve a problem involving measurement conversion
Obj. 28 - Convert a rate from one unit to another with a change in one unit
Obj. 29 - Convert a rate from one unit to another with a change in both units

**Topic 2 - The Number System**

Obj. 30 - Divide a multi-digit whole number by multiples of 100 or 1,000
Obj. 31 - Divide a multi-digit whole number of up to seven digits by a 3- or 4-digit whole number
Obj. 32 - Determine the multiplication expression involving rational numbers that is equivalent to a given division expression
Obj. 33 - Divide a fraction by a fraction
Obj. 34 - WP: Divide a fraction by a fraction
Obj. 35 - Add two or more decimal numbers of differing places to thousandths
Obj. 36 - Subtract two decimal numbers of differing places to thousandths
Obj. 37 - Multiply two decimal numbers through thousandths
Obj. 38 - Divide a whole number or a decimal number through ten thousandths by 0.001
Obj. 39 - Divide a 1- to 3-digit whole number by a decimal number resulting in a quotient that contains thousandths or ten thousandths
Obj. 40 - Divide a decimal number through ten thousandths by a 1- or 2-digit whole number or a decimal number through hundredths
Obj. 41 - Find the greatest common factor of two whole numbers less than or equal to 100
Obj. 42 - Find the least common multiple of two whole numbers less than or equal to 12
Obj. 43 - Apply the distributive property to determine an equivalent expression
Obj. 44 - WP: Represent a quantity using a positive or negative number
Obj. 45 - Identify or locate an integer on a number line
Obj. 46 - Identify a positive or negative rational number represented by a point on a number line
Obj. 47 - Determine the opposite of an integer given a number line
Obj. 48 - Determine the location of a rational number on a horizontal or vertical number line
Obj. 49 - Determine the location of an ordered pair in any quadrant
Obj. 50 - Relate the locations of two ordered pairs that differ only by signs
Obj. 51 - Identify the quadrant for an ordered pair
Obj. 52 - Determine the ordered pair of a point in any quadrant
Obj. 53 - Compare two integers
Obj. 54 - Order positive and negative integers
Obj. 55 - Relate a statement of inequality to the relative positions of two rational numbers on a number line
Obj. 56 - Compare positive and negative rational numbers
Obj. 57 - Order positive and negative rational numbers
Obj. 58 - WP: Determine a statement of order for rational numbers in context
Obj. 59 - Interpret a statement of order for rational numbers using context
Obj. 60 - Determine the absolute value of a rational number shown on a number line
Obj. 61 - WP: Solve a problem using absolute value to describe magnitude
Obj. 62 - Solve a problem by graphing points in all four quadrants

**Topic 3 - Expressions and Equations**

Obj. 63 - Determine the exponential notation that represents a repeated multiplication
Obj. 64 - Evaluate a whole number raised to a whole-number exponent
Obj. 65 - Determine an exponential form of a whole number
Obj. 66 - Use a numerical expression involving whole-number exponents to represent a multiplication expression
Obj. 67 - Evaluate a numerical expression with parentheses and exponents, using order of operations
Obj. 68 - Identify parts of an expression using mathematical terms
Obj. 69 - Use an algebraic expression with one operation to represent a verbal expression
Obj. 70 - Use an algebraic expression with two operations to represent a verbal expression
Obj. 71 - Evaluate an algebraic expression with one variable and two or three operations, using whole-number substitution
Obj. 72 - Evaluate an algebraic expression with two variables and two or three operations, using whole-number substitution
Obj. 73 - Evaluate an algebraic expression involving whole-number exponents
Obj. 74 - WP: Evaluate an algebraic expression or formula with one or two variables involving whole numbers
Obj. 75 - WP: Generate a table of paired numbers based on an algebraic expression with two operations
Obj. 76 - WP: Evaluate an algebraic expression involving exponents
Obj. 77 - Identify equivalent algebraic expressions
Obj. 78 - Determine solutions to a 1-variable linear inequality
Obj. 79 - WP: Use an algebraic expression with one variable and one operation to represent a situation
Obj. 80 - WP: Use an algebraic expression with one variable and two operations to represent a situation
Obj. 81 - Solve a 1-step equation involving whole numbers
Obj. 82 - Solve a 1-step equation involving fractions
Obj. 83 - WP: Use a 1-variable 1-step equation to represent a situation
Obj. 84 - WP: Solve a 1-step equation involving positive rational numbers
Obj. 85 - WP: Write an inequality of the form $x > c$ or $x < c$ to represent a constraint or condition
Obj. 86 - Represent the solution of an inequality on a number line
Obj. 87 - Relate coordinates to a graph and a table
Obj. 88 - Determine the algebraic expression with one operation for a table of paired numbers
Obj. 89 - Determine the graph of a 1-operation linear function
Obj. 90 - WP: Identify an algebraic equation with one operation for a table of paired numbers
Obj. 91 - WP: Use an algebraic equation to express one quantity in terms of another
**Topic 4 - Geometry**

Obj. 92 - Determine the area of a triangle
Obj. 93 - Determine the area of a parallelogram
Obj. 94 - WP: Determine the area of a triangle
Obj. 95 - Find the area of a polygon composed of triangles and rectangles
Obj. 96 - WP: Find the area of a polygon composed of triangles and rectangles
Obj. 97 - Find the volume of a right rectangular prism with fractional edge lengths using unit fraction cubes
Obj. 98 - Relate volume found using unit cubes to multiplication of edge lengths in a right rectangular prism
Obj. 99 - Find the volume of a right rectangular prism with fractional edge lengths using a formula
Obj. 100 - WP: Find the volume of a right rectangular prism with fractional edge lengths using a formula
Obj. 101 - Determine the location of the vertices of a polygon on the Cartesian plane
Obj. 102 - Find a side length of a polygon on the coordinate plane
Obj. 103 - WP: Find a side length of a polygon on the coordinate plane
Obj. 104 - Determine a net of a 3-dimensional shape
Obj. 105 - Determine the surface area of a cube or a rectangular prism given a net Obj. 106 - WP: Find the surface area of an object using a net

**Topic 5 - Statistics and Probability**

Obj. 107 - Use a dot plot, histogram, or a box plot to represent data
Obj. 108 - Report the number of observations in a data set
Obj. 109 - Determine the mean of a data set
Obj. 110 - Determine the median of a data set
Obj. 111 - Determine the interquartile range of a data set
Obj. 112 - Determine the mean absolute deviation for a data set
Obj. 113 - Describe overall patterns and deviations within a data set
Appendix G

**Topic 1: Rations and Proportional Relationships - 6th Grade Common Core**
Obj. 1 – Relate a ratio to a diagram

1. The parallelogram below is made up of 64 small triangles. All the small triangles are the same size and shape. What is the ratio of the unshaded area to the shaded area of the parallelogram?

   - [A] 4:3
   - [B] 1:3
   - [C] 3:4
   - [D] 3:1

**Topic 2: The Number System - 6th Grade Common Core**
Obj. 34 – Divide a fraction by a fraction

1. Ms. Yu makes control units for electric wheelchairs. Each unit uses a computer chip 3/32 inch long. At her work station, Ms. Yu has a row of chips 3/16 inch long. How many control units can she make?

   - [A] 2
   - [B] 3
   - [C] 1
   - [D] 5

**Topic 3: Expressions and Equations - 6th Grade Common Core**
Obj. 67 - Evaluate a numerical expression with parentheses and exponents, using order of Operations

1. \((15 + 3) \cdot 20 – 8^2\)

   - [A] 792
   - [B] 296
   - [C] 4
   - [D] 11

**Topic 4: Geometry - 6th Grade Common Core**
Obj. 92 Determine the area of a triangle

1. What is the area of the triangle?

   - [A] 144 ft²
   - [B] 40 ft²
   - [C] 45 ft²
   - [D] 39 ft²
Topic 5: Statistics and Probability - 6th Grade Common Core
Obj. 111 - Determine the interquartile range of a data set

1. There are 7 newborn kittens in a litter. These are their weights in ounces: 2.2, 2.4, 2.5, 2.6, 2.9, 4.2, and 4.8. What is the interquartile range of their weights?

[A] 1.8oz  
[B] 3.1oz  
[C] 2.6oz  
[D] 0.8oz

Topic 1: Number and Operations in Base Ten: Operations Multi-digit Whole Numbers – 5th Grade Common Core
Obj. 1 - Multiply a 3-digit whole number by a 2-digit whole number

1. 397 x 65 =  
[A] 26,805  
[B] 25,905  
[C] 25,805  
[D] 26,905

Topic 2: Number and Operations in Base Ten: Decimals - 5th Grade Common Core
Obj. 17 - Compare two decimal numbers through thousandths

1. Which statement is true?
[A] 0.427 < 0.43  
[B] 0.427 > 0.43  
[C] 0.427 = 0.43

Topic 3: Operations and Algebraic Thinking - 5th Grade Common Core
Obj. 41 - Evaluate a numerical expression of three operations with parentheses, using order of operations

3. 3 x (11+ 3) - 10 =  

[A] 26  
[B] 32  
[C] 60  
[D] 12

Topic 4: Number and Operations: Fractions - 5th Grade Common Core
Obj. 61 - WP: Add or subtract mixed numbers with unlike denominators that have no factors in common

1. For a school project, Abigail is keeping a log of her activities. One day, she spent 2 5/12 hours reading for fun and 2 2/5 hours doing homework. How much time did she spend reading and doing homework in all? Simplify the answer if possible.

[A] 4 8/17 hr  
[B] 4 7/17 hr  
[C] 4 49/60hr  
[D] 4 4/5 hr
1. Each month Adam changes the amount of food and sunlight a potted plant receives. When he started the plant was 75 cm tall. In the first month the plant grew 11 cm. The following month, the plant grew 2 times as much as it did the first month. How many meters tall is the plant at the end of the second month?

[A] 0.97 m   [B] 0.88 m   [C] 1.61 m   [D] 1.08 m

13. Which statement is true?

[A] A parallelogram is always a rhombus.
[B] A parallelogram is sometimes a rhombus.
[C] A parallelogram is never a rhombus.