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**Hands-On Mathematics: The Effects of Reinforcing Key
Mathematics in a Science Class for At-Risk Students**

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Abstract

This action research adds to the current body of research regarding the effects of integrating mathematics and science to improve achievement and confidence in at-risk students. Students in a high school general science class explored the relationship between motion and the slope of a line made by a distance - time graph. The intent was to provide them with a real world example of a concept they struggle with in mathematics class, slope. Quantitative data from pre-assessments and post-assessments was collected and found to show improved achievement in both areas by all students. Qualitative data from student reflections implied improved confidence in the ability to calculate slope among most students. The research takes into consideration current research on at-risk students, their identification and their learning needs. It also discusses how the current national standards in mathematics and science provide for and encourage integration of the two topics.

*Dedicated to my students, good and bad, who together,
have made me a better teacher and a wiser person*

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CHAPTER 1

Introduction

“I just can’t do mathematics.”

“I’ve never been good at it.”

“When it comes to mathematics, he’s on his own.”

These are statements educators hear from students and parents alike. In fact, students in my high school general science class admit to ‘just skipping any mathematics they come across’ while reading their science textbooks. They do not understand it, they have little confidence when it comes to using mathematics, and they have developed strategies to get around using mathematics as a result. Mathematics is the language of science, and if a student skips it they are unable to engage in scientific study since they have no way to analyze their data, look for patterns, and make meaning out of seemingly coincidental phenomena that can occur in the natural world. Why do some students avoid mathematics? What can teachers do to help low level and at-risk mathematics students achieve the high standards set for them?

Statement of the Problem

I have taught everything from high school Physics and Chemistry to 7th grade life science and mathematics to students of varying abilities and attitudes towards mathematics. Although every student has unique strengths and weaknesses, it is the students who struggle with mathematics but love science that intrigue me. I have always felt that science makes mathematics make sense, so I look for ways to apply the mathematics they avoid to the science activities they enjoy.

It is not just my students who struggle with mathematics. Students traditionally classified as at-risk for failing consistently lag behind their classmates on national and state tests.

According to the National Center for Education Statistics (NCES), in 2008, 17 year olds with

disabilities who took the National Assessment for Education Progress (NAEP) scored 32 points, almost three year behind students without disabilities (NCES, 2012; Loveless, 2008).

Furthermore, low SES students scored, on average, 20 points behind their classmates. Students with parents who did not finish high school scored 24 points behind students with parents who graduated from college. On the Wyoming 2011 state test, Proficiency Assessment for Wyoming Students (PAWS), 75% of students on IEP's and 50% of students qualifying for free and reduced lunches scored Basic or Below Basic¹ on the mathematics portion (Wyoming Department of Education, 2012).

While new sets of standards for mathematics and science set high expectations for all students, educators must find ways to make efficient use of the limited time they have with students in order to close the gap for students who trail their classmates in mathematics. One possible solution could be using other content areas, such as science, to reinforce and integrate basic and critical mathematics such that at-risk students can gain a better understanding and appreciation for both topics.

Defining At-risk Students

“At-risk students” is a widely used term that can have multiple definitions. For the purposes of this paper, a traditional definition of “at-risk students” will be extended to include students with disabilities who are currently or have formerly been on individual education plans (IEP), 504 plans, or behavior plans. It shall also include students with low socioeconomic status (SES) who qualify for free and reduced lunch according to the Federal Government. In addition,

¹ A score of Basic or Below Basic is considered not proficient in a particular area such as reading, mathematics, or writing. Proficiency rates are used to calculate a school's Adequate Yearly Progress (AYP) for NCLB.

at-risk students will include students who speak another language at home and are learning English at school, commonly referred to as English Language Learners (ELL).

For reasons that I will make clear, I wish to broaden my study to include students who fit a more non-traditional definition like the students described in the work of Dr. Andrea Honigsfeld and Dr. Rita. Dunn. Dr. Dunn has completed extensive research on strategies for teaching at-risk students. Because of their classroom and research experience, they have added to the definition of at-risk by claiming that it should also include “chronic underachievers” and “typically performing adolescents” who never seem to excel in academics (Honigsfeld & Dunn 2009). These students are the ones who appear bored and disengaged in a regular classroom setting. They may doodle when they should be working or have trouble remembering and comprehending what they read. They are the students who cannot seem to sit still and do not thrive when asked to do seatwork. Some may have diagnoses of attention deficit disorder (ADD) or attention deficit hyperactivity disorder (ADHD), while others may have undiagnosed troubles. While this is a broader definition, it is necessary to include all students who struggle in a traditional classroom setting instead of just the students who happen to have documented problems. Many students who struggle have been tested for IEP’s and do not qualify. Unfortunately, these students cannot legally receive additional support from special education staff and so therefore, slip further and further behind as they advance through school. They are the students who fall quietly through the cracks and are tempted to drop out when they turn sixteen.

New Mandates For Mathematics and Science

Both the CCSS-M State Standards for Mathematics (National Governors Association, 2012), hereafter referred to as the CCSS-M, and the Next Generation Science Standards (NGSS),

hereafter referred to as The Framework. These new science content standards were developed by a partnership of researchers including National Research Council, the National Science Teachers Association, Achieve, and the American Association for the Advancement of Science. The Framework for K-12 Science Education was the first step in developing NGSS. Both the CCSS-M and The Framework, are calling for all students to gain an understanding and appreciation for mathematics and science so that the United States can continue to be competitive for 21st century jobs. The authors of the CCSS-M call for “equity” stating that “The Standards should be read as allowing for the widest possible range of students to participate fully from the outset, along with appropriate accommodations to ensure maximum participation of students with special education needs (NGA, 2012; p.4).” Likewise, the Framework echoes the CCSS-M and emphasizes that science is for all students, stating that, “it is especially important to note that the above goals are for all students, not just those who pursue careers in science, engineering, or technology or those who continue on to higher education (NRC, 2012; p.9).”

Using science as a concrete application of mathematics may be an answer to a common question heard by mathematics teachers, “When will I ever use this?” Furthermore, this type of cross-curricular integration may help close the gap for low-achieving and at-risk students who need a concrete application to fully appreciate and understand mathematics.

Both sets of standards not only have the concept of equity in common, but there is also significant cross-over of mathematical and scientific concepts. The CCSS-M provides examples for teaching concepts such as graphing and slope, which would traditionally be done in a science classroom (NGA, 2012). For example, under the eighth grade standard “Expressions and Equations,” students are required to “understand the connections between proportional relationships, lines, and linear equations.” Specifically, they are to

Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways. For example, compare a distance-time graph to a distance-time equation to determine which of two moving objects has greater speed (p. 54).

Meanwhile, the Framework (NRC, 2012) recommends that k-12 science education be based on three major dimensions: core disciplinary concepts, cross-cutting concepts, and scientific and engineering practices. Integration of mathematics appears as the fifth scientific and engineering practice, *Using mathematics and computational thinking*. According to the Framework (NRC, 2012), “Mathematics enables ideas to be expressed in a precise form and enables the identification of new ideas about the physical world (p.51).” The Framework encourages students to actively learn science by observing, measuring, and using mathematics to represent their data and look for patterns so that they can extend what they have learned to other natural phenomena. For example, it specifically states that the use of probe-ware such as Calculator Based Laboratories (CBL) can and should be used to help students “transition from concrete mathematics to abstract algebraic reasoning” (NRC, 2012, p. 66).

While the challenges set forth by these reforms may be reachable for most students, at-risk students may have more difficulty (Honigfeld & Dunn, 2009). Research on the effects of integrating topics from separate disciplines for at-risk students has demonstrated positive results in improving the students’ skills and attitudes towards their work in both subject areas (Seki, 2007; MacMath, 2010; Judson, 2000). Additionally, according to Singh (2002) and Kajander (2008), students who are considered to be at-risk for failure in mathematics need to see more relevance in the mathematics they do and they need to be actively engaged in their learning. Kinesthetic and hands-on activities usually done in a science class may provide the practice for the mathematical content. As recommended by both the CCSS-M and the Framework, by the

end of high school all students should have developed an understanding of the interrelationship between mathematics and science as well as a working knowledge of how to apply mathematics to real world situations and problem (NGA, 2010; NRC, 2012).

Purpose and Scope of the Project

So what can be done to assist students in understanding the mathematics? Can hands-on activities in science class be used to enhance and provide relevance for key mathematical concepts that students, especially low-achieving and at-risk students, struggle? Science is a natural application of mathematics and easily provides relevance. The purpose of this action research project is to determine whether integrating a specific concept in mathematics into an existing science curriculum will improve the at-risk student's understanding of the specific science concepts while increasing confidence in manipulating applicable mathematical concepts. The intent is to use engaging and hands-on science activities to provide experiences that are relevant and interesting to students so that they may have a concrete application for mathematics and a deeper understanding and appreciation for both subject areas.

Research Questions

This research will be guided by the following research questions:

- 1) How could key mathematical concepts be reinforced in a science classroom?
- 2) Why should key mathematical concepts be reinforced in a science classroom?
- 3) What effect will reinforcing the key mathematical concept of *slope*, using motion as an application, have on the at-risk student's understanding and confidence with each topic?

Chapter 2

Review of the Literature

Introduction

Since the 1950's America has expressed a need to be the number one nation in the world in the areas of mathematics and science. Numerous research studies have been funded and new reforms have swept through the school system. Throughout the various reform efforts, two goals have remained constant. American education should produce the best students in the world, and we must ensure that all students achieve at high levels. Initially, in the 1950's and 1960's U.S. lawmakers funded education reform because of a growing need to be the first country to develop new technologies in atomic weaponry and space exploration (Woodward 2004). Still today, being the top nation internationally is a high priority. In one of his Weekly Addresses (2011), President Barack Obama said,

It is time to raise our standards, up our game, and do everything it takes to prepare our children to succeed in the global economy. Now is the time to once again make our education system the envy of the world (Weinstein, 2012 p. 1).

Although some reform efforts have had a different emphasis, many are aimed at improving student performance to make American students more competitive in the international arena. As these reforms were being realized in the public schools, a new subgroup of at-risk students emerged.

Identification of At-Risk Students

Title I and Identification of Low SES subgroup. With the civil rights movement and the implementation of The Elementary and Secondary Education Act of 1965, came an equity-based education reform leading to funding for Title I programs. Title I was developed initially to improving achievement in a newly identified subgroup of students from low-income families, or

low socio-economic status (SES). At the same time, the first National Assessment of Educational Progress, (NAEP) test was administered in 1969 to measure the academic achievement of American students in the areas of mathematics and reading (National Commission for Educational Statistics (NCES, 2013). Following this assessment, as part of the *Back to the Basics* reform effort, a large-scale study of poverty and mathematics education called *Project Follow Through* was conducted. This study concluded that small group direct instruction strategies were considered the most effective pedagogical methods for “disadvantaged (low SES) students” (Woodward, 2004). Coupled with a new emphasis on basic mathematics fluency and traditional teaching methods combined with new Title 1 funding, schools could provide extra educational services, such as small group direct instruction, to low-income students and minority students (Jennings, 2012).

Special education from IDEA to RTI. In 1975, the Individuals with Disabilities Education Act (IDEA), a law providing equal educational rights to individuals with disabilities was enacted to guarantee “procedural rights and authority for parents to sue in court if their children did not receive services agreed to in a student’s individual education plan (IEP)” (Jennings 2012, p. 3). The education community now was testing and identifying students at risk for failure and providing necessary interventions to improve their education. Since its initial passage, IDEA has been reauthorized several times. In 2004, IDEA became the Individuals with Disabilities Education Improvement Act (IDEIA). It expanded special education by requiring districts to adopt an alternative method for identifying students in need of special education services. This method made it easier to identify students in need of special services by removing

the IQ discrepancy requirement.² One such alternative is a three-tiered approach to at-risk student identification and remediation called Response To Intervention (RTI). The RTI model uses scientific processes and student performance data to identify students and match them to interventions (Wedl, 2005).

Standards-based reform. Since the late 1980's and 1990's, mathematics education has become a standards-based reform aimed to improve problem solving skills and accountability (Jennings 2012). With a constant supply of new curriculum standards from the National Council of Teachers of Mathematics (NCTM), United States (US) schools were provided with guidelines outlining what students should know and be able to do at the end of each grade level (Woodward 2004; Jennings 2012). By 2001, all but one state adopted new mathematics standards. These standards focused on providing "rigorous content-area standards that would help push the US to become first in the world in mathematics and science" (Woodward 2004, p. 22). Now with standards in place, schools had goals for every student and those students not reaching these benchmarks could be identified for remediation. According to Jennings (2012), "the standards movement also has promoted greater equity. The same academic expectations are set for all students in a state, and far greater attention is being directed to narrowing the achievement gap between various groups of students (p. 5)."

This reform was supported by Presidents George H.W. Bush, President Bill Clinton, and President George W. Bush with the enactment of No Child Left Behind (NCLB) in 2001.

² Students qualifying for Special Services were required to show a 20 point discrepancy between their ability level and their IQ.

Currently NCLB requires all students, regardless of their academic abilities, to be ‘proficient’ on standards-based state assessments by 2014.

Defining At-risk Students

Who are these students in danger of falling behind? Dr. Rita Dunn is a professor of Instructional Leadership at St. Johns University in New York, and Dr. Andrea Honigsfeld is an associate dean in the Division of Education at Molloy College in Rockville Center, NY. They have done extensive research investigating the learning styles and classroom needs of at-risk students. Dr. Dunn is a co-author of at least 4 different studies dating back to 1992 regarding the teaching and learning of at-risk populations. For the purposes of this study, Dr. Dunn’s definition of at-risk students will be used. She recognizes that the traditional definition of at-risk students may not be complete. Traditionally, at risk students are defined as students who:

- are diagnosed or misdiagnosed as learning disabled;
- grow up in isolated communities and do not begin learning English until they enter school;
- do not speak English because they have recently arrived from another country;
- live in poverty and lack basic and educational resources in their homes;
- are the children of migrant workers or undocumented immigrants whose presence in our schools is transient; or are homeless and do not have their basic needs of safety and security met (Honigsfeld and Dunn 2009).

However, this definition is incomplete according to Honigsfeld and Dunn. There are many students who are “chronic underachievers” or are “typically performing adolescents” but never seem to excel in academics whom she also characterizes as at-risk. These students may characterize one or more of the following:

- process new and difficult information globally and find it difficult to follow analytic, step-by-step teaching;
- do not seem to try or take school seriously (e.g., draw or doodle while listening; appear bored, tired, or listless);
- are nonconforming or disobedient (e.g., refuse to remain in their seats);
- cannot sit still, concentrate, or pay attention to the teacher for more than a few minutes;

- may read, but cannot remember and often do not understand what they read (Honigsfeld & Dunn 2009).

Standardized Testing to Track Progress

Throughout the different reform efforts, standardized testing has provided data to lawmakers and educators regarding subgroups of students such as those with disabilities or who are considered to be at-risk. In 1988 Congress redesigned the existing Exploratory Committee for the Assessment of Progress in Education (ECAPE) and formed the National Center for Education Statistics (NCES). A Commissioner of Education Statistics and a 26 member governing board, made up of a variety of stakeholders including legislators, educators, business leaders, and members of the general public, were appointed by the U.S. Department of Education to administer the National Assessment of Educational Progress (NAEP) every four years. The NAEP test was to be a “common yardstick” to provide “results on subject-matter achievement, instructional experiences, and school environment for populations of students” in fourth, eighth, and twelfth grade across the U.S. (NCES, 2013). In 1990, NAEP began a bi-annual assessment that could provide more detailed data disaggregated by state in the areas of mathematics, reading, science and writing.

In addition to bi-annual testing in these four core areas, NAEP administers a Long Term Trend (LTT) assessment which has been given every four years since the first test in 1969. Its purpose is to identify growth over time in U.S. students in mathematics and reading. The LTT data has provided educational information about subgroups including minorities, females, family income, and English language learners since 1970 (NCES, 2013).

At-risk Students Falling Behind

Table 1 compares 2008 LTT NAEP scores in mathematics of subgroups traditionally used to identify an at-risk population of students to those of average U.S. students generally not characterized as at-risk. That is, those identified with disabilities are compared with others without disabilities, who are not eligible for free/reduced lunch, or who have parents with college degrees.

Table 1:

2008 NAEP LTT Mathematics Scores for 17 year-old American Students with and without Disabilities.

At-Risk Student Subgroups	Score	Not At-risk Student Subgroup	Score
IEP, 504, other disabilities	277	No disabilities	309
Federal Student Lunch Program Eligible	292	Not eligible	316
Parent Education < 12 th grade	292	Parent Education -College	316

While both populations have shown little improvement over that past eight years, at-risk students are consistently 20 to 30 points lower than their higher achieving counterparts (NCES 2012). While this may not seem like a significant difference on the 500 point scale, analysts from The Brown Center on American Education consider 11 scale score points to be “approximately equal to one year of learning (Loveless 2008).” Additionally, for each of the data listed in Table 1, significance tests were performed by the NCES website as the reports were generated. All differences reported were considered by NCES to be statistically significant.

Ideas from Singapore

Following the 2003 Trends in International Mathematics and Science Study (TIMSS), Singapore students ranked first, and U.S. students ranked 16th out of 46 nations. According to Ginsburg (2005), “scores for U.S. students were among the lowest of all industrialized countries.” As a result, a study, led by Alan Ginsburg of the American Institutes for Research (AIR), explored the Singapore education system and compared it to that of the U.S. In January of 2005 they released a report that focused on four critical areas of each system: frameworks, textbooks, assessments and teachers. First, researchers found that Singapore has a very logical framework, which requires fewer topics to be covered each year at a more in-depth level than

U.S. frameworks. Students master topics and do not repeat them. Instead, they build on previously mastered topics in subsequent grades. Second, Singapore mathematics teachers use “rich problem-based textbooks,” and give “challenging mathematics assessments (ix).” Third, Singapore encourages their best students to become teachers.

The final and probably most relevant bit of information from the 2006 AIR report sheds light on what the U.S. could learn from how Singapore handles its slower students. Singapore assesses the mathematical ability of each student at the end of first grade and begins implementing interventions where slower students learn identical mathematics as the other more advanced students but at a slower pace. Their at-risk students are given more time to learn the same concepts at the same depth, but more importantly, they are taught by “expert teachers.” Ginsburg draws a clear contrast when describing how U.S. schools typically provide remediation for their at-risk population.

At-risk students often receive special assistance from a teacher’s aide who lacks a college degree. As a result, the United States produces students who have learned only to mechanically apply mathematical procedures to solve routine problems and who are, therefore, not mathematically competitive with students in most other industrialized countries (AIR 2005, xiv).

Ironically, it is the at-risk student that especially needs the hands-on activities to stay engaged during class (Honigsfeld & Dunn 2010; Seki 2007).

A Response From the CCSS-M

The *CCSS-M State Standards for Mathematics*, hereafter referred to as the CCSS-M, is a set of mathematical standards for schools, which is designed to move U.S. mathematics education “towards greater focus and coherence (NRC, 2012).”

For over a decade, research studies of mathematics education in high-performing countries have pointed to the conclusion that the mathematics curriculum in the United States must become substantially more focused and coherent in order to improve mathematics achievement in this country (NRC, 2012).

The CCSS-M takes many of its ideas from the Singapore study such as requiring fewer mathematical concepts to be covered each year, but in greater depth and the idea of equity, that mathematics is for all students of all abilities. It states, “all students must have the opportunity to learn and meet the same high standards if they are to access the knowledge and skills necessary in their post-school lives (NRC, 2012, p.4).” At the same time, however, the CCSS-M also admits that “[t]he Standards set grade-specific standards but do not define the intervention methods or materials necessary to support students who are well below or well above grade-level expectations (p.4).”

To assist teachers and curriculum developers in finding ways to reinforce key mathematical concepts for all students, the CCSS-M recommends that educators help students connect mathematical content to mathematical practice. This can be done most easily with standards that begin with “understand.”

Those content standards, which set an expectation of understanding are potential points of intersection between the Standards for mathematical content and the standards for mathematical practice. These points of intersection are intended to be weighted toward central and generative concepts in the school mathematics curriculum (NRC 2012).

It is these content standards that have the most potential to be integrated with other school subjects to give at-risk students and others more opportunities to make connections between mathematical content and practice.

The Framework Agrees

The 2011 *National Science Education Standards, K-12 Framework*, hereafter referred to as The Framework agrees with the CCSS-M in that it calls for a more competitive group of American graduates with better science and mathematical literacy. “Many recent calls for

improvements in K-12 science education have focused on the need for science and engineering professionals to keep the United States competitive in the international arena (NGA Center 2012, p.7).” Like the CCSS-M, a central idea in the Framework is that the Science content standards are for all students, not just the college bound. The K-12 framework encourages all students to observe, measure, and use mathematics to represent their data and look for patterns so that they can extend what they have learned to other phenomena. Again, equity is a central concept in The Framework, just as it is in the CCSS-M.

The goal of educational equity is one of the reasons to have rigorous standards that apply to all students. Not only should all students be expected to attain these standards, but also work is needed to ensure that all are provided with high-quality opportunities to engage in significant science and engineering learning (p. 29).

To help satisfy this need, the Framework, organizes the concepts to be taught into three major dimensions, 1) scientific and engineering practices, 2) cross-cutting concepts that unify scientific disciplines, 3) core ideas in physical science, life science, earth and space science, and engineering, technology and applications of science.

The integration of mathematics appears as the fourth and fifth scientific and engineering practice, “Analyzing and Interpreting Data,” and “Using Mathematics and Computational Thinking,” respectively.

The overall objective [of the practices] is that students develop both the facility and the inclination to call on these practices, separately or in combination, as needed to support their learning and to demonstrate their understanding of science and engineering (NRC, 2012, p. 49).

According to the Framework, “Mathematics enables ideas to be expressed in a precise form and enables the identification of new ideas about the physical world.(p. 64)” Furthermore, “Mathematics serves pragmatic functions as a tool—both a communicative function, as one of the languages of science, and a structural function which allows for logical deduction (p. 64).”

Traditionally, U. S. students, who lag behind their classmates in mathematics, are given more low-level problems and worksheets (Honigsfeld & Dunn 2010). However, according to Honigsfeld & Dunn (2010) many at-risk middle and high school students tend to be tactual and kinesthetic learners and “the best strategies for engaging tactual and kinesthetic learners’ minds are to engage their hands and bodies with manipulative instructional resources or to allow them to learn on their feet (Honigsfeld & Dunn 2010, p. 221).”

The current science and mathematics standards require all students learn and be able to apply certain critical concepts. However, many students do not respond well to a traditional teaching style in which students memorize processes, procedures, equations, and algorithms without a clear idea of why they do these things (Honigsfeld & Dunn, 2010). Without relevance or a practical application, mathematics is a foreign language to many at-risk students (Singh, 2002). How do these students learn best?

Best Practices for Teaching At-Risk Students

Dr. Patricia Popp, a College of Education professor at the University of William and Mary, interviewed six award-winning teachers of at-risk and highly mobile (transient) students. She found the following to be true about these teachers.

They had high expectations of students and were committed to ensuring that students had what they needed to succeed. Teachers maintained high student engagement and used a variety of instructional activities and a wide range of cognitive levels in the questions asked during their instruction, which was primarily teacher-directed (Popp 2011, p.275).

The most successful teachers of at-risk students have certain qualities in common. They run efficient, well-managed classrooms and they make personal connections with their students. Research has identified the following best practices used by top teachers of at-risk students. These include maintaining a caring environment, holding high expectations, using a variety of

structured teaching methods which are engaging and relevant and allowing opportunities for repetition (Furner 2005; Kajander 2008; Singh 2002; Seki 2007; Popp 2011).

Caring teachers holding high expectations. According to Popp (2011) “effective teachers of at-risk or highly mobile students meet affective needs by caring for and interacting with students, being fair and respectful, being enthusiastic and motivating, having a positive attitude toward teaching, and being reflective practitioners (p.277).” Muller (2001) conducted a longitudinal study of at-risk students and their teachers to investigate the effect that a caring teacher had on at-risk students’ mathematics achievement. Survey results showed that a caring teacher caused all students, including those considered by their teachers to be at-risk of dropping out, to give more effort, that caused the teacher to hold higher expectations for the students.

Engaging and relevant activities. In addition to maintaining a caring environment, teachers of at-risk students should be diligent in providing structured activities that are engaging and relevant. A study done by Singh (2002) showed two truths about student achievement in both mathematics and science. Although there are many variables that affect a students’ motivation to do well in these areas, these studies looked at only those variables that the school system had an opportunity to change. These school-related variables included academic engagement, perceptions and attitudes, and knowledge of the role of mathematics and science in future achievement and career opportunities.

Singh identified about 3200 U.S students who had standardized test scores on file for both science and mathematics. They sent surveys to each student with a bank of questions covering four topics relating to each of the school related variables mentioned above. After considerable statistical analysis the data revealed the following two truths.

First, students need positive experiences with mathematics and science before high school. Positive experiences give students good confidence and more determination when doing increasingly difficult mathematics and science. They also contribute to an increased motivation to do homework, which in-turn promotes better attitudes and eventually better mathematics and science achievement (Singh 2002).

Secondly, mathematics needs to be relevant and interesting. While educators cannot change a student's cognitive ability or home background, they can change classroom behavior, homework time, attitudes and perceptions of mathematics and science. If students are interested because they have found a practical way to use mathematics in their life, they are more likely to enjoy mathematics and want to do more of it (Singh 2002).

Another study led by Judith Seki (2007) indicated that in addition to providing relevance for mathematics, science may also improve mathematics anxiety. "Not only does mathematics enhance science learning, but that science reinforces mathematics as well (p. 67)." Her research followed class of 23 high school females labeled at-risk for failing mathematics through a four week unit on mechanical advantage in a science classroom. Post-test results showed the students had a much better working knowledge of mechanical advantage. Results also showed "a further advantage of this situation is that the students displayed little mathematics anxiety (p. 67)." The class viewed mathematics as a "sideshow" rather than the "main event." These factors made students less conscious of the fact that they were really doing mathematics! As a result, they had a more favorable opinion of mathematics and more confidence in their abilities to manipulate ratios (Seki et.al, 2007).

Kinesthetic teaching strategies. Dr. Rita Dunn's learning style responsive approach to teaching centers around the assumption that many at-risk students who do not respond well to

traditional teaching methods require “tactual and kinesthetic” strategies to fully understand content (Honigsfeld & Dunn 2009). In making this claim, she cites her 1992 study and five others ranging from 1987 to 2007. She states that, “the best strategies for engaging tactual and kinesthetic learners’ minds are to engage their hands and bodies with manipulative instructional resources or to allow them to learn on their feet (Honigsfeld & Dunn 2009).”

However, too often at-risk and lower level mathematics students are given textbooks and worksheets of which they are to complete independently or with the help of para-professionals who are not highly qualified teachers (Pugalee, 2001; Kajander, 2008). Both Pugalee (2001) and Kajander (2008) agree that mathematics classrooms should be a place where students are active participants in their own learning and where they see relevance and importance in doing their mathematics.

Furner, Noorchaya, and Duffy (2005), professors of mathematics at Florida Atlantic University, helped author an article in 2005 titled *Teaching Mathematics: Strategies to Reach All Children*, which outlined 20 strategies that are useful in teaching mathematics to at-risk students. Furner et.al agrees with Dunn, in that “using auditory, visual, and kinesthetic teaching approaches for different learning styles enables teachers to reach more students than the traditional direct-instruction or paper and pencil drill and practice forms of instruction” (p. 21). Additionally, he stresses the importance of relevance and of putting problems into contextual situations that students can identify with. Furner et al. list two more strategies that embody this concept; “make interdisciplinary connections to what students are learning in mathematics” and “apply problems to daily life” (p. 19). In doing so, students understand the universality of mathematics and can see its relevance in their lives.

Repetition. After providing a structured and caring environment where students solve problems by participating actively in their learning and can see the relevance in their activities, repetition is the final step. At-risk students participating in studies done by Judson (2000) and MacMath (2010) improved their mathematics achievement when they were given additional opportunities in other classrooms to practice the skills and concepts they were learning in science and mathematics.

Judson (2000) conducted an action research study aimed at promoting integration of mathematics and science using technology. Following professional development on using calculator based laboratories (CBL), two teachers at a Jr. High chose to use CBL technology in the science classroom to enhance a notoriously difficult statistics unit. Students were given CBL's and very open-ended questions to investigate relationships in science. Then they graphed their results using a variety of charts and graphs to display their data. In mathematics, they learned statistics the traditional way all other students did, with lecture and reinforcing worksheets.

Results showed the integrated mathematics class outperformed the other two mathematics classes (comparison group) not doing any integration in science. In the comparison group, 54% received D's or F's on the unit test and only 35% earned A's and B's. In the integrated class, however, the scores were markedly better; only 4% (one student) earned a D or and F and 75% received A's and B's. Both teachers cited repetition and familiarity with graphs and graph reading as reasons for the students' success (Judson, 2000).

In 2010, a Canadian study highlighted the importance of repetition across subject areas. In Canada, not all students complete the same high school curriculum. Students who are identified as "at-risk" for school failure by poor attendance, poor academic behaviors, or because

they have failed their previous classes take an alternative curriculum in high school which sets them up for trade school or the work place (MacMath, 2010). Two teachers, geography and science, decided to integrate a unit about energy. During the integration, the researchers focused on two questions. “Does curriculum integration effect the motivation levels of at-risk students and if so, how? In addition, what do at-risk students learn (if anything) during an integrated unit (MacMath, 2010, p. 88)?” In addition to the curriculum, teachers were focused on improving at-risk students’ self-efficacy by giving them ample chances to be successful. They hypothesized that “the value of integration for at-risk students may move beyond repetition to providing students with the opportunity to experience success. This opportunity, in turn, may have a positive effect on student self-efficacy (MacMath 2010, p.93).”

In the end, the results were very positive. Six out of seven students knew the content well and stated it was because of the repetition. Additionally, the survey given at the end about motivation showed that students felt the content was more relevant to their lives and that they would like to do more units like this one. While they were not willing to “work through their lunch hour” on the unit, they did enjoy it. Observations of on-task behavior support these findings also. Students were more engaged in both classes (MacMath, 2010). “The value of integration for at-risk students may move beyond repetition to providing students with the opportunity to experience success. This opportunity, in turn, may have a positive effect on student self-efficacy (MacMath, 2010, p.93).”

Using science class to provide additional practice and practical application of central concepts in mathematics is an efficient way to provide the hands-on and active learning necessary to teach at-risk and lower level mathematics students (Seki 2007; Judson, 2000). An interesting study conducted by Arnett (2009) showed successful mathematics integration at the

college level. It answered a similar question as this research is answering, “Will students perform better in mathematics, and have a better disposition toward mathematics, if it is taught in the context of science (Arnett, 2009)?”

A small college in Maine conducted a survey which revealed that incoming science majors were hesitant about taking mathematics courses required for their degree. To intervene, researchers set up a voluntary course which integrated biology and algebra courses. The professors used a stream ecology study to integrate the two subjects. When students signed up for classes in the Fall semester, they could choose to take the integrated class or take the two classes separately, thus creating a natural comparison group.

To assess whether or not integrating biology and algebra improved performance and disposition with regard to mathematics, researchers used final grades from the integrated class as well as survey and focus group results. A summary of the results indicated that students enrolled in the integrated class did significantly better in algebra than those in the two classes independently. Students in the focus group made the following five statements regarding their experience:

- Students agreed that they still liked biology better than algebra;
- Students agreed, though, that it is good to have the mathematics instructor in biology lab, especially when using graphing calculators;
- Students liked having their mathematics professor in biology lab because it helped them apply the algebra to their biology project;
- Students stated (unprompted) that they learned how to apply mathematics to science, and that it is important to their career;
- Students felt they could read scientific articles better after this experience (Arnett 2009, p.33).

In contrast, students enrolled in the two classes separately could not even see where the algebraic concepts they were learning could be applied to biology. Researchers found that:

it is important to be transparent with students regarding learning goals, and the deliberate connection of mathematics and biology to each project. Sometimes students miss these points and then don't realize that they just conducted a lot of algebra (Arnett 2009, p.33)!

This study provides support once again that integrated mathematical reasoning into science classes is not only necessary to enhance communication of scientific findings, it is also necessary to understand the meaningful use of mathematics. In addition, the researchers also noted "that it is important to be transparent with students regarding learning goals, and the deliberate connection of mathematics and biology to each project. Sometimes students miss these points and then don't realize that they just conducted a lot of algebra (Arnett 2009, p.33)!"

Defining Integration

What may be evident is how each of the research projects just mentioned regarding integration is differently organized and implemented. Purposeful integration of mathematics and science needs a common definition among educators (Hurley, 2001). Integrating these two topics is certainly not a new idea as there is a century of research on the topic. In order for integration to be effective and purposeful, teachers must know what and how to integrate and be given the time to plan such units. As Hurley (2001), found, "there seems to exist, a paradox between the demand for a general definition of integration and research that illustrates a need for multiple definitions (p. 265). After reviewing 31 studies integrating mathematics and science Hurley found that mathematics/science integrated units fell into one of five categories ranging from sequential integration in which "science and mathematics are planned and taught sequentially, with one preceding the other," to total integration in which the two topics "are taught together in intended equality (Hurley, 2001, p. 263)." Whether the different types of integration take place in the same classroom or separate classrooms or whether mathematics

precedes science or not, all five categories of integration suggest the need for either team planning, team teaching, or both.

An alternative view to integration comes from Robin Fogarty's book, *The Mindful School: How to Integrate the Curricula*. Fogarty (1991) describes curriculum integration as a continuum ranging from exploration within a discipline for concepts with reoccurring themes to models such as her "integrated model" which crosses disciplines. It is this integrated model which best describes the type of integration that this action research project models. "The integrated model views the curriculum through a kaleidoscope: interdisciplinary topics are rearranged around overlapping concepts and emergent patterns and designs (Fogarty, 1991, p. 64)." For this project, science curriculum was taught with a dual intent to reinforce a mathematical concept taught previously in the students' mathematics class and to enhance a science concept by applying mathematics.

Summary

To summarize, when teaching at-risk students, it seems that relevant problem solving is important. Both the CCSS-M and the Framework support the integration of mathematics and science concepts (NRC 2012; NGA, 2012). The Framework goes further saying that "Increasing students' familiarity with the role of mathematics in science is central to developing a deeper understanding of how science works (NRC, 2012, p. 65)."

When it comes to teaching at-risk students, they will work harder for teachers whom they perceive as caring (Popp et.al. 2011; Muller 2001). Activities in mathematics for at-risk students should be relevant and engaging (Singh 2002; Furner 2005; Seki 2007). Kinesthetic activities have are a powerful way to teach at-risk students because engaging their minds requires engaging their bodies (Honigsfeld & Dunn 2009; Furner 2005). Finally, integration provides

much needed repetition and confidence to the at-risk student (Judson 2000; Arnett 2009; MacMath, 2010). Additionally, careful thought and planning by a team of teachers is necessary for any type of meaningful and purposeful integration (Hurley, 2001; Frykholm & Glasson 2005; Fogarty, 1991).

Chapter 3

Methodology

Introduction

The authors of the CCSS-M State Standards for Mathematics call for integration of mathematical practices and mathematical content. In fact, the CCSS-M insists that, “Designers of curricula, assessments, and professional development should all attend to the need to connect the mathematical practices to mathematical content in mathematics instruction (NGA Center, 2012; p.8).” In other words, mathematics should be taught in context, not as an abstract, stand-alone discipline. Science is a natural application for mathematics and provides an excellent example of how and where students can find a practical use for their mathematics. In doing so, they may even be better equipped to do meaningful scientific analysis and draw conclusions which are based on sound mathematical evidence. This idea is also supported by the The Framework (NRC, 2012). “Increasing students’ familiarity with the role of mathematics in science is central to developing a deeper understanding of how science works” (p. 65).

Since the CCSS-M is calling for more integration, teachers must find methods to help students meet the new and more challenging goals lined out for them. While these challenges may be reachable for most students, at-risk students may have more difficulty. At-risk students whom do not respond well to traditional teaching methods can, many times, benefit from learning kinesthetically (Honigsfeld & Dunn 2009; Seki 2007; Furner 2005). The objective of this study is to determine the effects of purposefully integrating key mathematical concepts into an existing science curriculum with the intent to improve both the mathematical skills and mathematics attitude of a group of at-risk students.

Setting

The study took place in a rural area of a western state where two small towns exist within a few miles of each other. They have a collective population of approximately 2000 people. The school district, hereafter referred to as the District, is located in the larger of these two towns and serves students living in town and in the surrounding rural areas. In addition, the District lies half-way between two much larger cities on a major highway and so a number of students transfer into the district each year from larger schools these school districts. The District maintains an annual enrollment of about 700 students in four schools, an elementary school, a rural school, a middle school and a high school. It also employs 73 teachers and other certified staff, 61 para-educators or support staff, and 6 administrators. The high school houses approximately 200 students in grades 9-12, with 96% of those being Caucasian and the remaining 4% Hispanic, African-American, Native-American or Asian.

Parents in these towns find employment mainly in the energy field whether they work at a power plant nearby, the coal mines north of town, the railroad, or the oil and gas fields. Some individuals work at the school district while others commute to the neighboring cities for work. There are a few small businesses in these towns which employ some, but most are family businesses with only a couple of employees. Therefore many students come home to empty houses when their parents are still at work or are working shift work at the mines or the power plant. In fact, many high school students are tempted to drop out of school and work in the oil and gas fields or at the coal mines after receiving their GED.

Students

Although 20%³ of the District's students drop out or leave the district, the students who remain do fairly well academically as compared to other students in the state on the statewide assessment. These statewide test results on average over the past two school years show that 68% of high school juniors scored proficient or advanced in Mathematics, 79% in Reading, and 56% in Science. This is significantly better than the State averages which were 63%, 69%, and 47% respectively. While the District's scores may be higher than that of the state average, it must still meet the increasingly challenging Adequate Yearly Progress (AYP) goals lined out by No Child Left Behind (NCLB). When a district this small has on average just forty-five to fifty students being assessed each year, it is necessary to identify the students needing assistance and give them strategies for improving their statewide assessment scores. Causing improvement in the scores of just a few students can mean the difference between meeting our school's annual goal for AYP or not. This means that when it comes down to making marked improvement in these critical core areas it is about targeting a handful of students, eleven of which are students enrolled in General Science.

Teachers

The teachers at the high school are all considered "highly qualified" in the areas they teach. Like many of my colleagues I have several college degrees. I have a Bachelor's of Science in Exercise Physiology from a state university and a Bachelor's of Science in Education

³ The district graduated 40 out of 50 students in 2011. Therefore, it is important to keep in mind that 20% is 10 students, some of whom simply may have transferred to neighboring districts. Graduation rate is calculated using the number of students graduating compared to the number of students who entered as a class of students in 9th grade.

from a state college. I have a Natural Science field endorsement and a middle level mathematics endorsement. Therefore, I am considered by the U.S. Department of Education to be highly qualified to teach high school Earth Science, Chemistry, Physics, Biology, and middle school science and mathematics. This is my fourteenth year of teaching and my 7th year in the District. Interestingly enough, I taught at the middle school for the first 6 years of my tenure and then moved to the high school this year. Consequently, I was the eighth grade science and mathematics teacher for the students I currently teach in high school. It is a huge advantage to know the majority of the students I teach and what their unique strengths and weaknesses are.

Participants and Their Recruitment

Of the 200 students enrolled in the high school, 18 are enrolled in General Science as an alternative to taking Chemistry or Physics. The class is a junior level class but is also taken occasionally by seniors. It meets every other day on a 90 minute block schedule. The curriculum is designed to survey key ideas in Chemistry and Physics, so during the first semester, students learn the basics of atomic structure, physical and chemical changes, chemical nomenclature, and a small amount of stoichiometry. And then the second semester takes students through a study of energy, forces and motion, Newton's Laws, simple machines, and mechanical advantage.

Of the 18 students enrolled, I taught 17 in eighth grade physical science and seven of those seventeen were also in my middle school mathematics classes. They are now just bigger versions of their former 8th grade selves with a couple more piercings, some low hanging jeans, and some extra black eyeliner. They know me and they know that I will get them up out of their seats at some point during the 90 minutes of class for some sort of activity. They tell me constantly how they enjoy the hands-on activities and wish they could learn this way in all their

classes. Of all the classes I teach, General Science is the class I feel I know the best. We laugh and enjoy learning from each other just about every time I see them.

All students in the class were offered an opportunity to be a participant in this study. In addition, the study was outlined to parents who attended the fall parent-teacher conferences. Of the 18 students, 16 returned parental consent forms and signed student assent forms. These students were chosen as participants. All students were taught the regular classroom curriculum, but only data from those students participating was used for analysis.

Of the 16 participants, 4 are female, 12 are male, and three students have been identified as needing special services, and therefore, have Individual Education Plans (IEP). The group can be subdivided into 3 subgroups based on their Measures of Academic Progress (MAP)⁴ scores. Table 1 shows the students' scores on the fall MAP sorted from lowest to highest. Also shown is the result of their 2012 PAWS test in mathematics and whether or not the student is considered to be "at-risk" by the District.

⁴ The MAP test is a nationally norm referenced assessment which shows improvement in each student over the course of a school year and then compares each student's improvement to that of the national average.

Table 2

Participants' MAP test and statewide assessment scores

Gender	Grade	MAP Mathematics	Percentile Rank	Proficient PAWS Mathematics?	At-Risk?
*M	11	211	10	N	Yes
F	11	218	18	N	Yes
M	11	224	27	N	Yes
M	11	230	38	N	Yes
*M	11	231	40	N	Yes
*M	11	232	42	N	Low
M	11	234	46	N	Low
F	11	235	48	N	Low
M	11	235	48	Y	Low
F	11	239	57	Y	No
M	11	239	57	Y	No
M	11	240	59	N	No
M	11	243	64	Y	No
M	11	245	68	N	No
M	11	245	68	Y	No
M	11	246	70	Y	No

*Indicates students with IEPs.

Table 2 shows that most participants were significantly low in mathematics. The district identifies students as “at-risk” for failing if they test at or below the 40th percentile as measured by the MAP test. These students are recommended for the RTI program. Five of the 16 students, or 33% fall in this category while four are low level mathematics students with scores between the 40th and 50th percentiles. Therefore, nine of 16 students, or 50% of the class, are low or at-risk for failing mathematics as measured by the MAP test.

The district uses MAP test three times per year; once at the beginning of the school year to identify students needing intervention or remediation, once at the end of the first semester to track progress, and once again in May to show progress over the entire school year. The district then uses these results to identify its at-risk student population. All teachers are made aware of

students who have been identified so that attempts can be made to target each student's unique academic needs throughout the school year. There is no formal remedial program for students who are low but not on IEP's other than what individual teachers do in their classrooms with these students.

Data Collection

The research used data from pre-assessment and post-assessment data from participants in the general science class. A 40-question mathematics attitude survey was given to all participants before and after the study to determine each student's attitude change, if any, during the research. In addition, qualitative data from student and researcher journals was also used to help measure student attitudes.

Initially, a baseline was established for each student using the mathematics attitude surveys, student journal topic #1, and the pre-test scores. This baseline showed the class's understanding and confidence with the mathematical and scientific concepts to be studied before the start of the unit. Next, all students enrolled in the class completed a three week study of energy and how it affects motion. During the study, the researcher wrote field notes while observing student dynamics during the classroom activities. Students were also asked to reflect on their classroom experiences each day to provide feedback to the researcher. Finally, the post-test and final mathematics attitude surveys were administered. The results were analyzed and reported on in Chapter 4.

Data collection instruments

Pre-assessment and post-assessments. Throughout the unit a number of data collection instruments will be used. First, a pre-assessment and post-assessment will be used to determine whether students are learning what is being taught, and gauge the level of understanding each

students has regarding the content. This assessment was modified from an existing pre-assessment used by Physics teacher, Fredrick Graff. The assessment is designed to determine a student's understanding of and ability to interpret a distance - time graph. There are nine questions which ask students to determine relative speed, direction, and distances from a scenario about a visitor to the former ninth planet, Pluto, and a graph of the trip. There are two questions asking students to calculate slope once from a graph and once from two coordinates.

Mathematics Attitude Inventory. Martha Tapia's Attitude Towards Mathematics Inventory (Tapia, 1996) will also be administered before and after the study to determine the student's initial attitudes about mathematics. This study has been validated and found to be reliable in a 1996 study done by the author (Tapia 1996). It is a forty question survey using a five point Likert scale which measures four aspects of mathematics attitude as defined by the Tapia. These four areas are (a) students' confidence with mathematics, (b) whether or not they see value in mathematics, (c) their motivation to do mathematics, and (d) whether or not they enjoy doing mathematics. Because of the short timeframe that this project will take place during, the researcher expects to see very little change in the attitudes these students have taken years to form, never the less, another inventory will be administered and analyzed after the study is complete to determine any change in attitudes.

Misconception probes. The probes used, *Probe 4: Rate of Change, Slope I* and *Probe 4a: Rate of Change, Slope II*, were taken from a book authored by Cheryl Rose, Leslie Minton, and Carolyn Arline, *Uncovering Student Thinking in Mathematics*. According to the authors, the probes were developed with the assistance of Dr. Page Keeley and her process for designing diagnostic assessment probes (Rose, 2007). Dr. Keeley and others have developed research based assessment probes for all topics of science and mathematics. The probes used are two

part probes which include a multiple choice question in which any or all of the choices could be valid. Part 2 is an open-ended question designed to uncover student thinking and justification for the answer given in Part 1. The first was given after reviewing with the class how to calculate slope from a graph and from two coordinates. The second probe followed two lab activities in which students constructed distance-time graphs and discussed slopes of graphs in general terms. Following the lab activities, the second probe was given at the beginning of a class period with no review to determine the amount of knowledge of slope students could recall without help.

Student and researcher journals. The students were asked to reflect on the day's activities by writing journal entries. These reflections had prompts like the examples shown in table 12 to help measure student understanding, participation, and attitudes regarding each activity. In addition, the researcher wrote a summary of the lesson taught each class period, observations of student interactions, and highlights of conversations had with students about the content. Both student and researcher journal entries will be used to help remember the sequencing of work that took place and to help answer questions about mathematics attitude in the participants.

Summary of Classroom Activities

The curriculum dictates that, "Students will use the concept of energy and its forms in a variety of lab and problem-solving situations (CCSD Science Curriculum, 2009, p.26)." The objectives for the unit and the corresponding CCSS-M standard and NSES K-12 Framework (NRC, 2012) standard are as shown in Table 3. Table 4 contains information about specific classroom activities students participated in during the study and how each activity aligned with either NSES content or CCSS-M Mathematics content.

Most activities contained aspects of both mathematics and science. During each activity, mathematics was used as a tool to further analyze and support or disprove hypotheses made by

the students or the teacher. Most activities required students to be up out of their seats as an active participant in the production of graphs, or busy conducting measurements for a lab activity. All post-lab discussions were teacher led with students providing data from their lab experiences to answer the questions and solve the problems posed by the teacher. Students were then asked to write a reflection. Sometimes the reflections were left up to the students to discuss what they learned, but most of the time students were given specific questions to answer about the day's activities which could be used to determine individual understanding of critical ideas.

Table 3:

Alignment of District Objectives with CCSS-M and NSES.

District Objective and Component	The Framework	CCSS-M Standard
GS.5.01 Students will use the concept of energy and its classes and forms in a variety of lab and problem-solving situations.	Physical Science: PS2: Motion and stability: Forces and Interactions	8.EE. Understand the connections between proportional relationships, lines, and linear equations.
Define, measure, graph, and analyze relationships between distance, displacement, time, velocity, and acceleration.	Cross Cutting Concepts: Scale, proportion, and quantity	8.EE.5: “Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways. (For example, compare a distance-time graph to a distance-time equation to determine which of two moving objects has greater.”

Note: Adapted from (NRC, 2012; NGA, 2010; CCSD Science curriculum, 2010).

Table 4

Schedule of Classroom Activities Designed to Integrate Mathematics and Science in a Study of Motion.

Classroom Activity	Science Content	Mathematics Content
VAK Vocabulary and Textbook Readings	Defining key science terms	Three practice problems with examples.
Domino Run	Students investigate relationships between distance, time, and speed using dominoes.	Simple calculations of speed using variables and equations such as $s=d/t$.
CBR Investigation 1	Students conduct investigations regarding speed, direction, displacement and time using CBR technology.	Students begin informally discussing steepness of the lines they see while conducting the investigations.
Mathematics Day	None	Students review the mathematical concept of slope and practice calculating from graphs and from two coordinate pairs.
Misconception Probe: Slope 1	None assessed	Slope calculations from a graph using axes.
CBR Investigation 2	Students are given 8 distance-time graphs to analyze, make predictions about, and reproduce using CBR technology.	Students compare a calculated slope of the lines they produce to a speed given on the CBR's to determine what they slope of the line means.
Graphing Stories	Students use knowledge of distance-time graphs to predict the shapes of graphs using short video clips from the following online site.	No calculations were done for this lab activity.
Misconception Probe: Slope 2	None Assessed	Slope calculations from a graph using axes.
Journey to the Bus Stop	Students match 10 distance-time graphs with explanations given.	Students must successfully calculate slope from a table to match each graph.

CHAPTER 4

Results and Discussion

“Slope is why I have to retake 2nd semester Algebra I.”
“The hands-on helped me figured out the [rise/run] equation.”
“I like mathematics like rats like cheese.
But it’s hard to put them [mathematics and science] together.”

Introduction

As previously stated, a group of sixteen average to at-risk mathematics and science students participated in the study. Three subgroups were identified using data from the fall MAP test given by the mathematics department. The MAP test ranks students by comparing them to students nationwide who take the test. Each time there is a new testing window and new national norms are released. The District then compares the students’ Mean RIT scores to reports released by MAP and identifies students who fall below the 40th percentile as at-risk. Students ranking above the 40th percentile are not considered at-risk. In fact students who are truly at-risk will fall “well below the 40th percentile and therefore, by setting the cut score at 40, the District’s at-risk population is sure to include all students in need of remediation (Perko, 2013).” Table 5 shows the ranges of scores and numbers of students in each subgroup.

Table 5

Organization of subgroups with Percentile Rank as measured by Fall MAP Mathematics Test.

Student Subgroup	Percentile Rank	Number of Students
Low (At-Risk)	10-40	4
Low-Average	41-50	5
Average – Above Average	51-70	7

Student Achievement Data

Pre-assessment and post-assessment data. After identifying the three subgroups, data from pre-assessments and post-assessments was collected and analyzed. Tables 6-9 compare

average number of correct answers given by students in each subgroup. Additionally, assessment questions were grouped by topic and correct answers for each topic were also compared. Topics included speed, direction, using axes, calculating velocity, and calculating slope. Students' pre-assessment and post-assessment scores were calculated to show a percent change. It is important to remember that while these percents may seem very large implying a huge improvement, but they are calculated using a very small sample size. Therefore, sometimes the percent change may only be an improvement on two or three questions. A copy of the pre-assessment and post-assessment can be seen in the Appendix (E). The question numbers related to each topic are listed under each topic heading. Responses for questions 10 and 11 were not used since all students answered them correctly and they did not relate directly to this study.

Table 6

Whole Group Average Number of Correct Responses on Pre and Post Assessments.

Whole Group (n=16)	Overall	Speed (1,3)	Direction (2,4)	Using Axes (5,6,7)	Calculate Velocity (8,9)	Calculate Slope (12,13)
Pre-Test Results	6.1	1.0	0.8	1.2	0.6	0.6
Post-Test Results	10.1	1.8	1.6	2.4	1.5	0.9
Total Possible	13	2	2	3	2	2
Percent Change	65.6	80.0	100.0	100.0	150.0	50.0

A 65% increase in correct responses was seen in the entire group. The biggest gains occurred in the areas of graphing reading in which students determine the direction, distances, times, and velocities from a given graph and scenario. These areas saw improvement over 100% with the largest gain being 150% improvement in the area of calculating velocity from the graph.

Modest improvement was seen in the students' ability to calculate the slope of a line from a graph and from two coordinate pairs.

Similar results were seen in the At-Risk subgroup of students as seen in Table 7. Students in this subgroup fall at or below the 40th percentile as measured by their fall MAP mathematics score. They are therefore, considered at-risk for failure in mathematics and targeted for intervention by the District. Results from the At-Risk Subgroup show a 69% improvement from the Pre-Assessment to the Post-Assessment overall with one of the largest gains occurring in the students' ability to calculate velocity from the graph, a 233% increase.

Table 7

At-Risk Group Average Number of Correct Responses on Pre and Post Assessments

At-Risk Group (n=4)	Overall	Speed	Direction	Using Axes	Calculate Velocity	Calculate Slope
Pre-Test Results	5.3	0.5	0.8	1.0	0.3	0.8
Post-Test Results	9.0	1.8	1.5	2.3	1.0	0.5
Total Possible	13	2	2	3	2	2
Percent Change	69.8	260.0	87.5	130.0	233.0	-37.5

On the Post-Assessment, one of the four students answered both questions relating to velocity correctly while the other two answered one of the two questions correctly. All three of these students missed and/or guessed when answering these questions on the pre-assessment.

Another large increase seen in these students was their ability to infer speed and direction from a graph. A 260% and 87% increase was seen respectively. Analysis of the pre and post assessments showed this subgroup of students had a common misconception that a negative

slope on a distance- time graph represented slowing down, not a change in direction. Evidence from the post-assessment suggests that this misconception was generally corrected.

While the results for calculating slope seem disappointing, a closer look at the post-assessments implies that these students know more about calculating slope than is seen in the data. Two of the four students correctly calculated the slope of a line through two points and two others tried but failed only because they incorrectly subtracted y-values from x-values instead of finding the difference between the two y-values and the two x-values. In other words, instead of using the equation, $m = \frac{Y_2 - Y_1}{X_2 - X_1}$, they used $m = \frac{Y_2 - X_2}{Y_1 - X_1}$. In addition, three of these four students guessed correctly on the pre-assessment on number 13 causing a seemingly 37% decrease from pre to post assessment when in actuality, two of the four students improved in this area and the other two made small improvements.

The Low-Average Subgroup showed the most marked improvement of all the subgroups from pre to post assessment with a 145% increase overall. Students in this group have difficulties with mathematics and fall between the 40th and 50th percentile as measured by the fall MAP mathematics assessment. While they are not considered at-risk, they do fall into the broader definition of at-risk mentioned in Chapter 2.

Table 8

Low-Average Group Average Number of Correct Responses on Pre and Post Assessments.

Low-Average Group (n=5)	Overall	Speed	Direction	Using Axes	Calculate Velocity	Calculate Slope
Pre-Test Results	4.0	0.6	0	0.4	0.6	0.6
Post-Test Results	9.8	1.5	1.5	2.5	1.5	1.0
Total Possible	13	2	2	3	2	2
Percent Change	145.0	150.0	150.0	525.0	150.0	66.7

They improved the most when asked to gain information by reading the axes. Out of 15 responses given on these questions three questions by this subgroup, only two were correct on the pre-assessment while 10 correct responses were given on the post-assessment for the same 15 responses.

When asked to calculate velocity from the graph, three of the five students were correct. Similar results were seen when these same three students calculated slope. Although they may not have answered correctly, the mistakes they made seemed minor. Two students simply gave the answers with the wrong sign while one student incorrectly gave the slope as “run/rise” instead of “rise/run.” In spite of these mistakes the subgroup still saw a 66% improvement in this area.

Students in the Middle-High Subgroup fall between the 50th and the 70th percentile as measured by their fall MAP Mathematics assessment score. While they are relatively good mathematics students to begin with, they made over 200% increases when asked to calculate velocity and slope from a set of coordinates or a graph.

Table 9

Middle-High Group Average Number of Correct Responses on Pre and Post Assessments.

Middle-High (n=7)	Overall	Speed	Direction	Using Axes	Calculate Velocity	Calculate Slope
Pre-Test Results	8.1	1.6	1.3	1.9	0.9	0.4
Post-Test Results	11.2	2.0	1.8	2.4	1.8	1.2
Total Possible	13	2	2	3	2	2
Percent Change	38.3	25.0	38.5	26.3	260.0	200.0

The most common mistakes made in these areas were not because of a lack of understanding but instead from careless errors. For example, on the post-assessment, five of the seven students missed Question 13 in which they were asked to calculate the slope from a graph of a line intersecting the y -axis at -2 . Their mistakes occurred because they calculated the slope from the graph correctly but did not make the sign positive. None of the students used two points on the line to calculate slope, however, all of the students were correct on Question 12 and were able to correctly calculate slope from two coordinate pairs.

Table 10

Answers and Quotes given on Slope I and Slope II Misconception Probes.

Student & Subgroup	Answers Slope I	Quote Slope I	Answers Slope II	Quote Slope II
<i>Correct Response</i>	<i>C,E</i>		<i>A, C, D</i>	
Student 1- At-Risk	A,C	"I guessed because sometimes I'm good at it."	A, B, D	"How I got my answers is I just guessed but [I chose the] graphs that were going up by 1."
Student 2 - Low-Average	B, D	"I kinda (sic) forgot how to do this so I guessed. I can't remember if it's based on slope or if its' based on the coordinates of the points that make up the line."	A, D	"A and D because they both go up at regular intervals."
Student 3 – Low-Average	C, E	"Rise over run, drafting class taught me how to calculate."	No Response	"I'm LOST, I tried to divide rise over run and none of them came out to be one."
Student 4 – Average-Above	B,C,E,F	"I circled these ones because they all have set numbers on the x and y axes (sic) and the line goes threw them all at the corners meaning the slope is moving at a change of 1 each time"	A,C, D	"A,C,&D are all at 1 because the rise & run both equal 1. You have to reduce the numbers and when reduced both A, C & D equal 1."

Misconception slope probe data. After being taught to calculate slope from a graph using the equation, $m = \frac{Y_2 - Y_1}{X_2 - X_1}$, students were given a probe, Slope I, from Cheryl Rose's book, *Uncovering Student Misconceptions in Mathematics*. After a number of lessons and labs on slope and velocity in which students made and interpreted distance - time graphs, students were given a second probe, *Slope II*. The results overall were mixed, however, some individuals showed improvement in using the axes to help calculate slope. Four student responses were selected from the group of 13 students completing both probes. Of these four, three showed evidence of improved understanding of slope while one showed evidence of increased frustration as a result of knowing more about how to calculate slope. Table 9 shows quotes from students regarding the first probe and second probe as well as their answers as compared to be correct responses for each probe.

Three of the four students showed improvement from the first to the second probe. Student 1 stated he guessed on both probes but had some reasons for his answers on the second probe. While he guessed correctly on one of the graphs on Slope I, he got two of the three correct on the second probe. Student 2 also showed an interesting response on both probes. He was incorrect on both of the Slope 1 graphs but showed some understanding that there is a relationship between the "numbers on the sides" and the slope. He was unable to give correct responses, because he "couldn't remember if it's based on slope or the coordinates of the points that make up the line." However, on Slope 2, Student 2 was correct on two of the three responses and much more confident in his answers. Student 4 also showed evidence of improvement. He knew on the first probe that he should be looking at the axes to calculate slope but from the responses he gave, it is evident that he was simply looking for a line that goes over one and up one instead of using coordinates of two points to calculate slope. However, on the

second probe, he was successful in ruling out Graph B which is meant to reveal student misconceptions regarding slopes that “go over one and up one,” but have different values on the x and y axes.

Student 3 is the only one of the 13 member group that initially, showed no improvement. However, after interviewing this student about his lack of response on Slope II, he said “I was over-thinking it, I should have just gone with my gut.” Initially, Student 3 had a fairly good understanding of how to calculate slope because he had experience doing it to determine the pitch of a roof in drafting class. His initial understanding helped him to correctly answer the Slope 1 probe because he was able to relate the numbers on the axes to the vertical and horizontal rise of a roof line. However, on Slope II, he did not make the same connection because he was trying to calculate slope mathematically and couldn’t make sense of the numbers he was getting. When asked why he did not just use the same process as he did the first, time, he stated, “the numbers from the x-axis and y-axis didn’t match up, so I got frustrated and quit.”

Student Attitude Data

Mathematics attitude inventory data. Martha Tapia’s Attitude Towards Mathematics Inventory was administered on the same day as the pre-assessment after receiving a scoring key and permissions (Tapia, M. personal communication, January 2013). Students were asked to give honest answers to the 40-question inventory. Again, this inventory breaks a student’s attitude toward mathematics down into four categories including self-confidence, motivation, value, and enjoyment. The inventories were collected and analyzed to prepare a snapshot of the class attitude toward mathematics as well as that of each student individually. Table 8 displays the class averages from the MAI in each of the four categories. The MAI numbers are based on a five point Lickert scale where five is a positive response and one is the most negative.

Table 11

Class and Subgroup Averages for the Mathematics Attitude Inventory in Each of Four Categories and Overall.

Groups	Overall	Self-Confidence	Motivation	Value	Enjoyment
At-Risk	2.3	2.3	2.1	3.0	1.8
Low-Average	3.1	3.3	2.7	3.7	2.7
Middle-High	3.2	3.6	2.7	3.4	2.9
Whole Group	3.0	3.2	2.6	3.4	2.5

As a whole, the class scored lowest in the areas of motivation and enjoyment, implying that while they may have confidence with and an understanding of the value of mathematics, they are not necessarily motivated to do it and they do not particularly enjoy it. Almost all students seemed to see the value in doing mathematics since this was the group’s highest and most positive rating. For example, the group’s response overall to Question 4, “Mathematics helps develop the mind and teaches a person to think,” received the most positive response at a 3.9. A more detailed look at the responses for this question reveals that 13 of 16 students agreed or strongly agreed and three were neutral.

In contrast, Question 25, “Mathematics is dull and boring,” had the most negative response from the class at an average of 1.8. As you may have noticed, some of the questions on this inventory are reversed, meaning that a high score on them means a negative response. For these questions, the numbers given by students were reversed to avoid confusing results. Therefore, the students who agreed that mathematics is dull and boring initially recorded a “4” or “5” that they agreed or strongly agreed. When the data was input for analysis, however, a response of “5” became a response of “1” and a “4” became a “2.” As a result, an average of 1.8

means that the class as a whole agrees strongly with this statement, since 10 of 16 students recorded they agreed or strongly agreed while the remaining students recorded a neutral response.

Another interesting trend was revealed when students' responses were averaged and then ranked from lowest to highest. Three of the four students in the At-Risk Subgroup as measured by MAP appeared to have the worst attitudes towards mathematics while one student scored much higher. This student is the same one who made the biggest improvements on the pre and post-assessments in this subgroup.

Student reflections. Following each activity, students were asked to complete a reflection about the activity or assignment they just completed. Sometimes they were given specific questions to answer and sometimes they were simply asked to reflect on what they learned, what was easy, and what was difficult for them. These reflections help determine the evolution of student attitudes towards mathematics and towards the types of activities as the unit progressed. To summarize their comments, all reflections were read and categorized by topic and date. Student comments are summarized in Table 12. Three students were selected because they had responses on file for all activities listed and because they wrote well enough to accurately communicate their feelings.

As can be seen, students all had more difficulty with the mathematics worksheet in which they were asked to calculate slope on a graph first by using rise/run and then to calculate slope from two points without a graph. Even the top students had trouble calculating slope from two points. Furthermore, the general attitudes were much more negative.

Following the worksheet, students investigated their own motion using CBR motion detectors. They noted the speed they walked using the gauge option on the CBR. Then they

reproduced their graphs on graph paper, causing them to study the x and y axes. Finally, they calculated the slope of the line on their distance - time graph and compared their answer to how fast they were actually travelling. After a class discussion, the responses were overall, very positive. Most students made the connection between finding slope and finding the velocity on a distance - time graph. While some still didn't fully understand slope, they all had more positive comments about the activity.

One of the final activities was the *Graphing Stories* activity. Students watched videos of people or objects in motion and then drew graphs to match the motion they saw. Following guided practice on whiteboards and teacher led discussions about each graph, students were asked to reflect on one of the videos they watched. The majority of students were able to provide excellent reflections about why the graphs looked the way they did.

Table 12

Summary of Student Reflections

Activity	Journal Prompt	Student 1 (At-Risk)	Student 2 (Low-Average)	Student 3 (Middle-High)
Calculating Slope Worksheet	How easy or hard was this worksheet?	“Hate all of it hard don’t like mathematics even more slope its dumb and worthless. I’m not good at mathematics and never will be.”	“I completely guessed on all of this, I don’t understand it at all.” “Slope is why I’m retaking 2 nd semester Algebra I.”	“This was more challenging for me then (sic) most other stuff because it’s different...If I have a graph it’s easier.”
CBR Investigation	How does the slope of a line on a distance - time graph represent how fast you are moving?	“Steep lines mean fast because your (sic) covering more distance in a shorter amount of time.”	“I still don’t understand slope very well, but there were some new things I learned that could help me later in mathematics.”	“The rise/run equation and distance/time equation are pretty much the same because they tell you how far you go how fast.”
Graphing Stories	Choose one story and explain how the graph you made represents the motion in the video.	“Balloon Length. I think the steeper the slope the higher the number for rise will be. And the one that’s not so steep would represent a longer time (run). That could fit with all the graphs.”	“In the distance from the bench video, the high points were when he had his arms fully extended and the line in between were how fast he was able to push the bar up. When he was stuck at the bottom, the line was flat until he was slowly able to push it back up.”	“In the Bum off the ground video the graph clearly shows when she is going down the slide where she went faster or slower. The line intermitintly (sic) gets steeper and shallower at the different parts of the slide.”

CHAPTER 5

Conclusions and Implications

“Mathematics is the language with which God has written the universe.”

~Galileo Galilei

The purpose of this action research was to determine if a more integrated study of science and mathematics would improve the knowledge and appreciation of the two subjects in at-risk students. A group of sixteen students explored the relationships between motion and slope in a high school general science class. Based on the research and data collected, the following conclusions can be drawn.

Student Achievement and Attitudes

First, those students participating in an integrated Mathematics and Science unit involving motion and slope gained a better understanding of both topics. The lowest half of the class made the biggest gains. They gained a better “big picture” idea of how slope relates to velocity. While they were not always able to calculate slope correctly, they did have a better idea of how to resolve slope problems. The upper half of the class made gains specifically in their ability to calculate slope from a graph and from a set of coordinates. They also made improvements in their abilities to interpret the meanings of distance - time graphs.

Second, all students enjoy doing hands-on activities, however just as Arnett (2009) found they do not always make the connection between the activities and the topics being taught. Careful construction of the activities with frequent teacher-led discussions worked well to help students make key connections. Research indicated that students classified as at-risk according to the definitions laid out in this paper benefited from hands-on activities. Teacher observations

and student notes have indicated the same. Hands-on activities allow students to have a concrete application of the mathematics.

Here is what some students had to say about a day when they were asked to do bookwork in which they calculated speed from examples in the textbook and then they conducted a lab in which they calculated the speed at which a string of dominos would fall. A student from the at-risk subgroup said, “Lab was fun more than reading the book and I just do not get what the point of the speed and velocity of dominos was.” Another student from the average subgroup remarked on the concrete application science provided for him. “I think that if I went through [the textbook] with a teacher to walk me through I would understand it better. Being able to use the equation with something that was actually their made it a lot easier to understand.” Finally, even a student from the highest subgroup felt the hands-on was worthwhile, saying, “It was easier after lunch because we did hands-on which is much funner (sic) to do.”

Finally, attitudes of at-risk students towards mathematics seemed to improve as long as the work did not “look like mathematics.” Student reflections showed that when confronted with a mathematics worksheet, it was as if the mathematics was staring them in the face and they had negative views of it. However, when asked to do the same task on a graph they made in the CBR investigations, students understood it and had a more positive feeling about it. Just as Seki (2007) found, if students see the mathematics as a “sideshow” and the science as the “main event” they are less anxious. It is at this low anxiety level when students in this class seemed to learn the best.

Implications for Teachers

Integrating science and mathematics may help improve achievement in both areas. This was a short project with very limited results. However, if purposefully integrating mathematics

has a long-term positive effect, the results could be amplified if students across grade levels learned mathematics and science together. This however, would necessitate professional development and cross-training between teachers of different disciplines. The current Professional Learning Community (PLC) model used by our district could be a powerful tool to begin a discussion of integration among teachers and administrators.

”There has been significant discussion of this action research project with the student’s algebra teacher. We found, as many do, that in order to fully integrate all the topics we teach, we would need common planning time. In addition, it would be necessary to discuss the specific vernacular that each discipline uses so that common words and phrases could be revealed for students. However, as Hurley (2001) suggests, total integration is just one type and all levels have been shown to be effective. Therefore, even a minimal level of integration such as done with this project, provides needed relevance and repetition for at-risk students.

How should Mathematics be Integrated?

A thorough exploration of both the CCSS-M and the Framework has revealed that there are many opportunities for integration, specifically in areas where the CCSS-M standards begin with “understand.” Additionally, as shown by Hurley and others, integration can take many forms that require discourse among educators from both disciplines. MacMath (2010) and Arnett (2009) found that the repetition and integrated units provide is helpful but that common language is needed for at-risk students to see the cross over. While Frykholm & Glasson (2005) remind us teachers need time and knowledge of both disciplines in order to integrate them effectively.

Why Should Mathematics be Integrated?

While the “how” may be still undefined by this research and that of others, the “why” is very clear. First, students in all subgroups demonstrated and reported a better understanding of

slope. Some specifically stated that the labs helped them “understand the [speed] equation better.” Just the daily repetition and experience of resolving mathematics problems relating to science activities has shown to give these students better confidence in mathematics. It certainly makes sense to use science to help in this area for those students who might be left behind in mathematics class.

Secondly, as Galileo observed, mathematics is the language of science and helps explain our natural world. This project and many other studies of integrated units have shown that integrating two units of study for at-risk students has improved achievement in both areas (Arnett, 2009; MacMath, 2010; Hurley, 2001). The CCSS-M repeatedly asks for students at all levels to “solve mathematical and real-world problems (NGA, 2012) while the Framework lists “Analyzing and Interpreting Data,” and “Using Mathematics and Computational Thinking,” as a “scientific and engineering practices” necessary for all students to do science well. This project suggests that integrating just one topic in one unit of study not only achieved the expected result of improving student understanding of the science of motion but also student confidence with and ability to correctly calculate slope.

Limitations and Topics for Another Study

This was a very limited study done with only 16 students during one unit of study. Therefore, the results given are only suggestions which hint at a way to improve mathematics and science education for at-risk students. Consequently, there are many questions left unanswered for future research. First, are seemingly minor mistakes really minor and what is the best way to understand the misconceptions behind these mistakes? The frustration of Student 3 had as he learned more about slope is evidence of a misconception but of what? The mistakes made by students when they incorrectly subtract y-values from x-values as mentioned in Chapter 4 may seem like simple mistakes but they imply a deeper problem. The students who made these

mistakes may not understand the reason for the procedure or the equation for slope. Therefore, the science application may have failed them. Science was supposed to supply meaning to the x and y-values. More work with researched based assessments such as the Misconception Probes would be a valuable addition to help get to the root of the problem with these students.

A second question left unanswered is still, how exactly, should mathematics and science be integrated? Should mathematics back-up science or should science back-up mathematics? I think it should be a little of both. Having taught both topics, I believe they should both back each other up whenever possible. Should the topics remain separate or should educators look to combine the two? Again, I believe both disciplines have a great deal of topics which are unique to each, however, where integration is possible, teachers should find structured and meaningful activities that force students to combine the two. These questions, however, could be great extensions of this research.

When studying mathematics history, one sometimes wonders which came first, mathematics or science. One of man's first recorded observations of his world was the study of the heavens. While his obsession with the movements of the stars and other heavenly bodies grew, so grew the need for more advanced mathematics and as new mathematics were discovered, new scientific explanations followed. It seems perfectly natural. However, it is rare that educators encounter students with this holistic view of nature. It seems, in this age of education, students have inherited a disconnected understanding of mathematics and science. Many do not see the two disciplines as the ancients did, as one study of nature, but if our youth were shown the many connections throughout their education, would they appreciate both mathematics and science even more? I think so.

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APPENDIX A

IRB APPLICATION

Institutional Review Board
Room 308, Old Main
1000 East University Avenue, Dept. 3355
Laramie, WY 82071

Application for Review of Research Involving Human Subjects

1. Responsible Project Investigator (RPI) and Faculty Supervisor (FS)

RPI:

Name: Jennifer Hornung	Title: Graduate Student
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FS:

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2. Title of Study:

Hands-on Mathematics: Reinforcing key mathematical skills in at-risk students using hands-on science activities.

3. Anticipated Project Duration:

Include specific dates:

1/1/2013 to 5/30/2013

4. Purpose of Research Project:

In LAY LANGUAGE, summarize the objectives and significance of the research:

At-risk students, who do not respond well to traditional verbal-linguistic teaching methods, typically prefer either kinesthetic or auditory learning. In fact, the absence of such strategies in a typical classroom may account for inflated identification of at-risk students. The objective of this study is to determine the effects of integrating key mathematical concepts into an existing science curriculum with the intent to improve both the mathematical skills and attitude of a group of at-risk students. For example, an important and basic concept like slope can be better understood by at-risk students using hands-on activities in a science setting. A secondary goal is to observe how a critically important concept in mathematics can be integrated and reinforced in the science classroom to benefit the education of at-risk students.

4. Summarize the literature related to this study in two paragraphs:

Both the Common Core State Standards for Mathematics (NGA Center, 2012) and the National Science Education Standards (NRC, 2012) are calling for more consistency and integration of mathematics and science nationwide. The new Framework for K-12 Science Education (NRC, 2012) hereafter referred to as The Framework, recommends that k-12 science education be based on three major dimensions including core ideas, unifying concepts, and scientific and engineering practices. The integration of mathematics appears as the fifth scientific and engineering practice, “Using mathematics and computational thinking.” According to the framework, “Mathematics enables ideas to be expressed in a precise form and enables the identification of new ideas about the physical world (NRC, 2012).” The Framework encourages students to observe, measure, and use mathematics to represent their data and look for patterns so that they can extend what they’ve learned to other natural phenomena. In fact it specifically states that the use of probe-ware such as CBR’s, can and should be used to help students transition from concrete mathematics to abstract algebraic reasoning (p. 66). Likewise, the Common Core State Standards for Mathematics (NGA Center, 2012) argue for a “more coherent and focused in order to improve student achievement”. The Standards also explicitly assure the readers that it was written after a careful study of a large body of supporting evidence. Specifically, they call for integration of mathematical practices in everyday lives of students. In particular, Standard 1: Make sense of problems and persevere in solving, them states that “mathematically proficient students can explain correspondences between equations, verbal descriptions, tables, and graphs or draw diagrams of important features and relationships, graph data, and search for regularity or trends” (pg. 8). Furthermore, Standard 4: Model with Mathematics, mentions that “[mathematically proficient students] are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions” (pg. 8).

While the challenges set forth by these new sets of standards may be reachable for most students, at-risk students may have more difficulty. According to Singh (2002) and Kajander (2008), students who are considered to be at-risk for failure in mathematics need to see more relevance in the mathematics they do and they need to be actively engaged in their learning. Kinesthetic activities usually done in a science class may provide the practice for the mathematics content. Additionally, research on the effects of integrating topics from separate disciplines for at-risk students has proven effective in improving the student’s skills and attitudes towards their work (Seki, 2007; MacMath, 2010; Judson, 2000). Therefore, integrating mathematics into the science at-risk students are learning should improve both their understanding of the mathematics because it is being reinforced in a different classroom and because it should provide the application and relevance they need.

5. Description of Human Subject Participants:

A. Age-range and gender: Students are high school juniors and seniors ages 15 to 19. There are both males and females in the class.
B. Describe how the participants will be selected: The students are enrolled in a General science class that follows a physical science curriculum.
C. Describe how the participants will be recruited: Students will be asked to participate and told pertinent details about the study.
D. Describe the number and type of participants expected (e.g. 44 - 4 th grade students, 2 - 4 th grade teachers): No more than 25 11 th and 12 th students will participate.
E. Incentive (if any) to be provided for participation : none
F. Description of special classes: (e.g. cognitively impaired, minorities, students, etc...) There is a subgroup of special education students enrolled in these classes, but none will be excluded.
G. Criteria for inclusion/exclusion from participant pool: No students in these classes will be excluded.

6. Procedure (this includes a DETAILED explanation of the research procedures):

A. Description of subjects' participation (e. g. what will they do and how long will it take?) The research will begin after receiving informed consent from parents and student assent from participants. Then, a regular unit on forces and motion will begin with a pretest covering the mathematical concepts to be integrated. Next, the class will then complete daily lessons that will include a variety of activities to teach the content. Following each lesson, students will reflect in their science journals about the day's lesson. (See Appendix). While students are reflecting and when there is time in class, the researcher will be keeping field notes. All data including student journals and researcher field notes will be written not recorded by video or audio. (See Appendix) The entire unit should last no longer than three weeks or seven class periods. (The class meets every other day for 90 minutes and 60 minutes when it meets on Fridays.) Upon completion the post-test will be given to assess skill development. The student journals will be used as both a formative and a summative assessment showing the students' perceptions of the lesson, the activities, and their attitudes. In addition, an inventory assessing mathematics attitude will be given well before the unit starts and again after its completion. This inventory is attached in Appendix G.
B. What will non-participants do while subjects participate? (If applicable) Any students in the class who are not participating will be assigned the same activities as the participants, however, their data will not be collected.

<p>C. What will subjects be told about the research project? Subjects will be asked to complete regular coursework in science class and journal about their experiences. It will be made clear that the work they do in class is the same regardless of their participation in this research project. They will also know that the work they turn in will be graded as usual but that copies of their work may be de-identified and used in this research project if they choose to participate.</p>
<p>D. Description of deception (if any): none</p>
<p>E. Subject time involved (frequency/duration): No extra time will be needed outside of the regular classroom.</p>
<p>F. Where will research take place? The study will take place at Glenrock High School in Room 203.</p>
<p>G. Method of data collection? Data will be collected from pretests and post-tests as well as from student science journals, field notes and class activities. All data will be de-identified.</p>
<p>H. When and how many subjects terminate participation? Anyone wanting to cease participation at any point can let the teacher (RPI) or the Supervisor (FS) know by using her contact information and their data will be removed from the study.</p>
<p>I. Description of biological samples? N/A</p>
<p>J. Description of equipment to be used on or by subjects: Calculator Based Rangers (CBR) probes will be used frequently to teach motion graphs. Use this link for details. http://www.vernier.com/products/sensors/motion-detectors/cbr2/</p>
<p>K. Where is data collected in classroom setting? (Provide specifics about what data will be collected for research analysis outside of the classroom (actual coursework samples, test scores, observation notes, etc.) and describe how it will be used; clarify whether the entire class will take the curriculum being studied, or if only a part of the class will use the curriculum being studied and part will continue the old/current curriculum as a control) The entire class will take pre-tests and post-tests and participate in the classroom activities, but only data from the responses of participants will be collected. Likewise, any teacher observations and field notes being made will be of participating students only. Data will then be coded and locked up so that the identities of students cannot be linked with their responses.</p>

7. Confidentiality Procedures:

<p>A. Explain whether or not subjects be identified by name, appearance, or nature of data. All information about students' names, ages, and gender will be coded so that individuals are not identifiable.</p>

<p>B. Explain the procedure that will be used to protect privacy and confidentiality? Names of participants will be coded so that no student is identified.</p>
<p>C. How and where will data be stored? Data will be kept in a locked filing cabinet in a locked office and/or on a password protect computer.</p>
<p>D. How long will it be stored? <i>The RPI shall maintain, in a designated location, all records relating to new research which is conducted for at least three years after completion of the research.</i></p>
<p>E. Who will have access to the data (and under what circumstances?) The researcher and the faculty supervisor will have access to the data.</p>
<p>F. Other confidentiality issues? none</p>

8. Benefits to Subjects:

<p>A. Describe the indirect research benefits for the participants: Students may benefit from using technology to understand graphing and graphical analysis as well as other hands-on activities to better understand mathematics and its relation to science. In addition, they may be better able to apply knowledge gained in these activities to other mathematical concepts. Likewise, the researcher may benefit from having a better understanding of how well kinesthetic activities work for teaching difficult concepts to difficult students.</p>
<p>B. Describe the direct research benefits (including monetary compensation or other tangible incentives to participate) or state there are no direct benefits to the subjects: none</p>

9. Risks to Subjects:

This should include a detailed description of any reasonably foreseeable risks or discomforts to the subjects as a result of each procedure, including discomfort or embarrassment with survey or interview questions, exposure to minor pain, discomfort, injury from invasive medical procedures, or harm from possible side effects of drugs. All projects are deemed to involve some level of risk to human subjects, however obvious or obscure. Proposals that state there is no risk must qualify exactly why there is no risk. Generally, there is always some risk, even if minimal.

Proposals must state that minimal risk is involved when the proposed research is viewed as involving little or no risk to human subjects. Risk is minimal where the probability and magnitude of harm or discomfort anticipated in the proposed research are not greater, in and of themselves, than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests. Even when risk is minimal, investigators must still state what the minimal is and why it is minimal.

Describe the risks to subjects:

Minimal risk exists such as a student could be frustrated by an inability to use the technology but no risk will be greater than what normally goes on in a classroom setting.

10. Description of procedure to obtain informed consent or other information to be provided to participant:

How, when and by whom will the subjects be approached to obtain consent:

The researcher will mail consent and assent letters home to parents and include a self-addressed stamped envelope for ease of their return to school. Follow-up calls will be made to anyone with questions about this project. These letters will go out as soon as this IRB application is approved.

How will information be relayed to subject (read to, allowed to read, audio-recorded, video-recorded)?

The forms will be read to the class and explained with all questions answered. Parents' questions will also be answered by email or phone.

If information will be audio or video recorded, the following information must be included in the proposal and the informed consent form:

1. Who will have access to the audiotapes, where the tapes will be stored, when the tapes will be destroyed (or that they will be kept indefinitely and why), and whether the tapes will be used in other studies or for future research
2. If the recordings will be kept indefinitely, the consent should state that subjects have the right to review and delete recordings that will be kept indefinitely or shared outside of the research team; and
3. A check-box or signature line for consent to be audio or video recorded (separate from the signature line for consent to participate) must be included on the form.

Provide a description of feedback, debriefing, or counseling referral that will be provided

N/A

Explain the procedure that will be used to obtain assent of children of an age and mental capacity deemed capable of providing such. (Note: Assent must be obtained in a separate document and/or in a separate location from the parent(s). Assent can be oral or written depending on age and maturity of the child.)

The parents will receive a copy of the student assent form with their consent form. Therefore, students may already have the form. These student and those that receive a copy of the form in class, will be asked to give their form, signed or not to a classroom aide to collect in an envelope.

Then, the names of participants will be coded from this point forward on all documentation. Any sample student work will be coded in the same manner.

For curriculum-based action studies conducted in classroom settings, student subjects may have to complete all the class assignments for the curriculum as part of their normal course work for a grade, but students (and their parents) are free to give or withhold their

permission for the investigator to use that work outside of the classroom for research.

11A. Description of Instruments (copies must be attached):

Instrument Name	Description	Source
Instrument 1:	Pre and post assessments (Appendix A)	Glencoe Physical Science and Glencoe Algebra I
Instrument 2:	Field Notes (Appendix B)	Researcher developed
Instrument 3:	Student Sample Work and Student Journal Response (Appendix C)	Student journal responses, short answers to questions on worksheets and daily work.
Instrument 4:	Attitude Towards Mathematics Inventory (Appendix D)	Tapia, Martha. (2008)

11B. Other Documents used to conduct the research (copies must be attached)

Document Name	Description (e.g.) letters, fliers, or advertisements used to solicit participation	Source
Document 1:	Parental Consent Letter (Appendix E)	Researcher developed
Document 2:	Student Assent Form (Appendix F)	Researcher developed
Document 3:	Superintendent and Principal Letter and consent (Appendix G)	Researcher developed
Document 4:	Approval from Faculty Advisor (Appendix H)	Lynne Ipina

12. Letter from faculty advisor (Must be attached if the RPI is a graduate or undergraduate student)

13. Letter of agreement (if subjects will be solicited through an institution such as a school or hospital) from the participating institution. (Must be attached) (principal and superintendent)

14. Consent Forms (Must be attached):

Informed consent is a process, not just a form. Information about the research must be presented IN CLEAR, UNDERSTANDABLE LANGUAGE to enable persons to voluntarily decide whether or not to participate as a research subject.

The procedures should be designed to educate the subject population in terms that they can understand. To be effective, informed consent forms must be written in "lay" language at an appropriate reading level to be understandable to the people being asked to participate or provide consent for a minor to participate. **The average individual only reads at an 8th grade level.** Informed consent forms should be written to the participant, for example, –You will be asked to fill out a survey. Requests for parental consent should be written to the parent referring to their child, for example, –I will ask your child to read aloud to the group, –Your child will be asked to complete a 3-page questionnaire.

Requests for participant assent (for subjects under 18 years of age) should be separate from the parental consent form and written at an age appropriate reading level. Assent can be obtained orally (but must be documented) depending on the age and maturity of the child.

Consent form outline:

Description	Completed
I. General purpose of the study: Why are you conducting this study? What do you hope to gain from this study? Why should subjects participate?	
II. Procedure: How and where will the study be conducted? Who will be conducting the study? What will the subject be expected to do? How much of the subject's time is needed?	
III. Disclosure of risks: State why risks involved in participation are minimal, or if the project involves more than minimal risk, describe in detail all potential risks of the study, and procedures to minimize risks.	
IV. Description of benefits: List any direct/indirect benefits to the subject, including compensation or incentive, if any.	
V. Confidentiality: What level of confidentiality will be afforded to subjects? How will confidentiality be protected? Who will have access to the data, how will the data be protected, and how long will the data be kept? Will the data be used for research purposes at any time other than the purpose(s) stated above? Please note that confidentiality cannot be guaranteed, but you can describe the methods you will use to protect confidentiality. Confidential and anonymous are not the same, please use the applicable terminology for your study.	
VI. Freedom of consent: Include a statement such as: "My participation (my child's participation) is voluntary and my (my child's) refusal to participate will not involve penalty or loss of benefits to which I am (my child is) otherwise entitled, and I (my child) may discontinue participation at any time without	

<p>penalty or loss of benefits to which I am (my child is) otherwise entitled."</p> <p>For studies involving classroom students: "I understand that my (my child's) refusal to participate or my (my child's) withdrawal at any point will not affect my (my child's) course grade or class standing."</p> <p>This statement should be written in language appropriate for the age and level of education of the subjects. Include procedures for subject, or parent/guardian on behalf of subject, to withdraw from study.</p>	
<p>VII. Questions about the research: Include name, address and phone number where principal investigator/faculty advisor can be reached during normal business hours. Also include the statement "If you have questions about your rights as a research subject, please contact the University of Wyoming IRB Administrator at 307-766-5320."</p>	
<p>VIII. Consent/assent to participate:</p> <p>_____</p> <p>Printed name of participant</p> <p>_____</p> <p>Participant signature</p> <p>_____</p> <p>Date</p>	
<p>IX. Parental consent required for all subjects under 18 years of age. Parental consent must include all the elements of a normal consent form and must be SEPARATE from the minor's assent (the minor and parent need to consider participation independently).</p> <p>PARENTAL SIGNATURE EXAMPLE: As parent or legal guardian, I hereby give my permission for (child's name) _____ (printed name of participant) o participate in the research described above.</p> <p>_____</p> <p>Printed name of parent/legal guardian</p> <p>_____</p> <p>Parent/legal guardian signature</p> <p>_____</p> <p>Date</p>	

APPENDIX B

DISTRICT LETTER OF CONSENT

Converse County School District No. 2
Post Office Box 1300 120 Boxelder Trail
Glenrock, Wyoming 82637
307-436-5331

October 25, 2012

Institutional Review Board
Room 308, Old Main
1000 East University Avenue, Dept. 3355
Laramie, WY 82071

To Whom It May Concern:


We are writing on behalf of Converse County School District #2 to inform the University of Wyoming Institutional Review Board (IRB) that Jennifer Hornung, a University of Wyoming graduate student and teacher in our school district, has permission to conduct a research study using the students in her General Science class as subjects. We are aware that the study will include only students whose parents have given informed consent for their children to be participants. In addition, Jennifer will gain student assent after parental consent has been given. Participants' names and other identifying information will not be printed or used in any part of her research study, and all documents identifying students will be kept in a secure location.

Furthermore, we are aware that her study will consist of teaching the regular curriculum as outlined by our school district, however, some of the participants' work may be used as samples and data from pre and post tests will be collected and reported as evidence for her research. Specifically, she will be researching how mathematical concepts can be successfully taught to at-risk math students in a science setting. Her research will begin as soon as IRB approval is given and the class reaches the standard, or outcome to be studied in our curriculum. The study will last no longer than one month or as long as it takes the class to finish that particular outcome.

Jennifer has agreed to provide to our offices a copy of the University of Wyoming IRB-approved, stamped consent document before she recruits participants.

Should you have any questions, please contact Kirk Hughes at 307-436-5331 or Mr. Chris Gray at 307-436-9201.

For Converse County School District #2


Kirk M. Hughes
Superintendent of Schools


Chris Gray
High School Principal

KMH:gs

APPENDIX C:

PARENT CONSENT

Dear Parents and/or Guardians,

I am writing to ask your assistance with a research project I am conducting as a part of my Master's Degree at the University of Wyoming under the supervision of Dr. Lynne Ipina. The following sections below outline the important facts you need to be aware of should you decide to give informed consent for your child to participate in the study.

Description of the Research

I would like to invite your child to participate in a **6 week research study** that I am conducting, as a graduate student at the University of Wyoming in the Masters of Science in Natural Science Program. Your child was selected as a possible participant in this study because he/she is enrolled in my general science course at Glenrock High School. In short, I will be teaching the regular classroom curricula for this class but will be purposefully integrating mathematics wherever possible to determine the possible benefits of teaching mathematics in a science setting.

What my Child will be Asked to Do?

If you choose to allow your child to participate, his/her classroom experience will be no different than that of non-participants. The only difference will be that your child's responses may be used in the analysis portion of my paper. Anything I use will be completely de-identified so that no names or other identifying information is shown. The classroom activities will include a pretest, classroom lessons involving hands-on science and mathematics activities, and a post-test. Students will be asked to write journal entries also, which will be a valuable piece of information.

Risks and Possible Benefits

Minimal risk exists such as a student could be frustrated by an inability to use the technology but no risk will be greater than what normally goes on in a classroom setting. To them, classes conducted during the study will not be any different than any other day. There is no cost for participating, Students may benefit from using technology to understand graphing and graphical analysis as well as other hands-on activities to better understand mathematics and its relation to science. In addition, they may be better able to apply knowledge gained in these activities to other mathematical concepts.

Protection of Privacy and Confidentiality

Your child's name will not be included in any of the data I use for this study. The information that is obtained in connection with this study will be kept confidential by using a coding procedure and the coding key will be kept separate from the data and will not be shared with anyone – not parents, other teachers, principal or anyone else. No other person besides me will have access to this information. ***I will maintain, in a secure location at the school, all records relating to new research which is conducted for at least three years after completion of the research***

Choosing to be in the Study

Your child's participation is voluntary. ***Your decision whether or not to allow your child to participate will not affect you or your child's relationship with me or Glenrock High School. Should you or your child wish to withdraw from the study at any time, please contact me immediately by email, jhornung@cny2.k12.wy.us, or by phone, 307-436-7454.***

Contact Information

If you have any questions about the study, please feel free to contact Jennifer Hornung at 307-436-7454, or her University of Wyoming advisor, Dr. Lynne Ipina, at 307-766-2318. If you have questions regarding your rights as a research subject, please contact the University of Wyoming IRB (irb@university.edu or 307-766-5320). You will be offered a copy of this form to keep.

Consent

Your signature indicates that you have read and understand the information provided above, that you willingly agree to allow your child to participate, and that you and/or your child may withdraw your consent at any time and discontinue participation without penalty. It also indicates you have been offered a copy of this form, and that you understand that you are not waiving any legal rights.

Printed Name: _____

Signature: _____ Date _____

APPENDIX D

STUDENT ASSENT

Dear Student,

I am writing to ask your assistance with a research project I am conducting as a part of my Master's Degree at the University of Wyoming under the supervision of Dr. Lynne Ipina. The following information will tell you about the project and your possible role in it. If you still have questions when you finish reading, please ask.

What is my research project?

I want to teach a unit in which I integrate mathematics wherever possible to determine the possible benefits of learning mathematics while you learn science. This research will take 6 weeks.

What will I be asking you to do?

If you choose to participate, ***your classroom experience will be no different than that of non-participants. The only difference will be that your responses may be used in the analysis portion of my paper. Anything I use will be completely de-identified so that no names or other identifying information is shown. The classroom activities will include a pretest, classroom lessons involving hands-on science and mathematics activities, and a post-test. Students will be asked to write journal entries also, which will be a valuable piece of information.***

What are the risks?

Minimal risk exists. For example, you could be frustrated by an inability to use the technology but no risk will be greater than what normally goes on in class. To you, classes conducted during the study will not be any different than any other day. Furthermore, you may benefit from using technology to understand graphing and graphical analysis as well as other hands-on activities to better understand mathematics and its relation to science. In addition, you may even be better able to apply knowledge gained in these activities to other mathematical concepts.

Is there cost?

There is no cost. You get to participate for FREE!

Will my name be used anytime in your research?

Your name will not be included in any of the data I use for this study. The information that is obtained in connection with this study will be kept confidential by using a coding procedure and the coding key will be kept separate from the data and will not be shared with anyone – not your parents, other teachers, principal or anyone else. No other person besides me will have access to this information. ***I will maintain, in a secure location at the school, all records relating to new research which is conducted for at least three years after completion of the research.***

Do I have to participate?

Your participation is voluntary. If you choose not to participate, nothing will be held against you, but you will still do all the same work as the rest of the class. Your decision whether or not to participate will not affect your relationship with me or the school. If you decide to participate, you are free to withdraw your assent and discontinue participation at any time.

How do I contact you if I have questions?

If you have any questions about the study, please feel free to contact Jennifer Hornung at 307-436-7454, or her University of Wyoming advisor, Dr. Lynne Ipina, at 307-766-2318. If you have questions regarding your rights as a research subject, please contact the IRB (irb@university.edu). You will be offered a copy of this form to keep.

Assent

Your signature indicates that you have read and understand the information provided above, that you willingly agree to participate, and that you know you may withdraw your consent at any time and discontinue participation without penalty. It also indicates you have been offered a copy of this form, and that you understand that you are not waiving any legal rights.

Printed Name

_____ Date _____

Signature

APPENDIX E: PRE-ASSESSMENT AND POST-ASSESSMENT

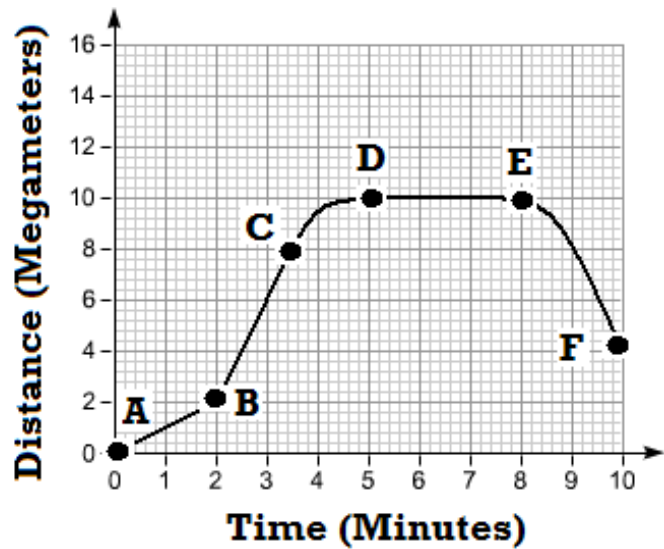
Graphing Motion Pre/Posttest:

Name: _____

The date after Pluto was demoted from its original status of 9th planet in our solar system, super woman noticed, with her keen telescopic vision, that a pulsar star was nearing poor little ex-communicated Pluto's orbit. In fear that her Plutonian friends who live on the planet would be injured, she took off at speeds faster than light to save them and bring them back. The graph below represents the distance-time of her trip. She leaves from Earth (point A), arrives at Pluto and stays for a period of time, and then begins her trip back. Please use this information to answer the following questions:

Use the following to answer questions 1 -5:

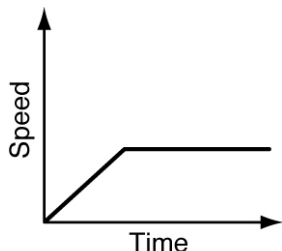
- a) A to B
- b) B to C
- c) C to D
- d) D to E
- e) E to F



- 1) Along her way to Pluto, between what points is she moving the fastest?
- 2) Between what points represent her arrival?
- 3) Between what points is she slowing down?
- 4) Between what points is she heading back to earth?
- 5) According to the graph, how far is Pluto from Earth (in actuality it's a bit further)?
- 6) When she completed the trip, how far was she from earth?
- 7) How long did the trip from Earth to Pluto take?
- 8) What is her velocity between points A and B?
- 9) What is her velocity between points D and E?

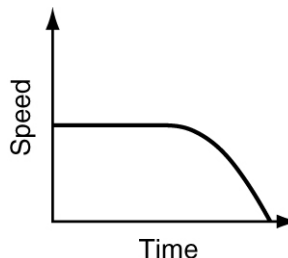
Select the best answer and record it in the blank at the left.

_____ 10. Which situation could be represented by the graph below?



- A. The speed increases and then decreases.
- B. The speed increases and then remains constant.

_____ 11. Which situation could be represented by the graph below?

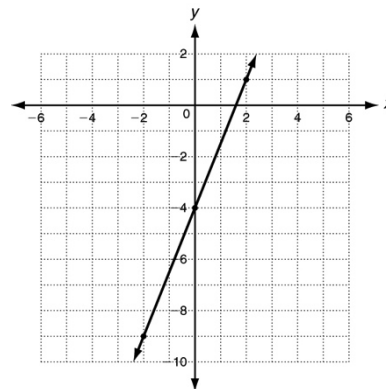


- A. A person slows down and then travels at a constant speed.
- B. A person travels at a constant speed and then slows down.
- C. A person travels at a constant speed and then speeds up.
- D. A person speeds up and then travels at a constant speed.

_____ 12. Find the slope of the line that contains the points (-1, 1) and (2, 8).

- A. 5
- B. $\frac{7}{3}$
- C. 3
- D. $\frac{1}{3}$

_____ 13. Find the slope of this line.



- A. $\frac{5}{2}$
- B. $\frac{2}{5}$
- C. $-\frac{5}{2}$
- D. $-\frac{2}{5}$

APPENDIX F:

ATTITUDES TOWARDS MATHEMATICS INVENTORY

Name _____

School _____

Teacher _____

Directions: This inventory consists of statements about your attitude toward mathematics. There are no correct or incorrect responses. Read each item carefully. Please think about how you feel about each item. Enter the letter that most closely corresponds to how each statement best describes your feelings. Please answer every question.

PLEASE USE THESE RESPONSE CODES:

SD – Strongly Disagree, D – Disagree, N – Neutral, A – Agree, SA – Strongly Agree

- ___1. Mathematics is a very worthwhile and necessary subject.
- ___2. I want to develop my mathematical skills.
- ___3. I get a great deal of satisfaction out of solving a mathematics problem.
- ___4. Mathematics helps develop the mind and teaches a person to think.
- ___5. Mathematics is important in everyday life.
- ___6. Mathematics is one of the most important subjects for people to study.
- ___7. High school mathematics courses would be very helpful no matter what I decide to study.
- ___8. I can think of many ways that I use mathematics outside of school.
- ___9. Mathematics is one of my most dreaded subjects.
- ___10. My mind goes blank and I am unable to think clearly when working with mathematics.
- ___11. Studying mathematics makes me feel nervous.
- ___12. Mathematics makes me feel uncomfortable.
- ___13. I am always under a terrible strain in a mathematics class.
- ___14. When I hear the word mathematics, I have a feeling of dislike.
- ___15. It makes me nervous to even think about having to do a mathematics problem.
- ___16. Mathematics does not scare me at all.

- 17. I have a lot of self-confidence when it comes to mathematics.
- 18. I am able to solve mathematics problems without too much difficulty.
- 19. I expect to do fairly well in any mathematics class I take.
- 20. I am always confused in my mathematics class.
- 21. I feel a sense of insecurity when attempting mathematics.
- 22. I learn mathematics easily.
- 23. I am confident that I could learn advanced mathematics.
- 24. I have usually enjoyed studying mathematics in school.
- 25. Mathematics is dull and boring.
- 26. I like to solve new problems in mathematics.
- 27. I would prefer to do an assignment in mathematics than to write an essay.
- 28. I would like to avoid using mathematics in college.
- 29. I really like mathematics.
- 30. I am happier in a mathematics class than in any other class.
- 31. Mathematics is a very interesting subject.
- 32. I am willing to take more than the required amount of mathematics.
- 33. I plan to take as much mathematics as I can during my education.
- 34. The challenge of mathematics appeals to me.
- 35. I think studying advanced mathematics is useful.
- 36. I believe studying mathematics helps me with problem solving in other areas.
- 37. I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in mathematics.
- 38. I am comfortable answering questions in mathematics class.
- 39. A strong mathematics background could help me in my professional life.
- 40. I believe I am good at solving mathematics problems.

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APPENDIX G:

MISCONCEPTION PROBES

SLOPE I

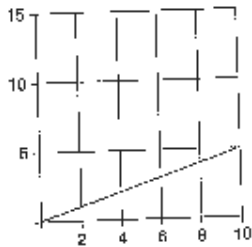
106 UNCOVERING STUDENT THINKING IN MATHEMATICS



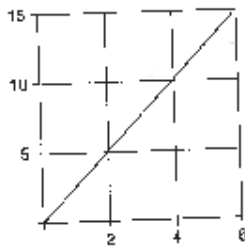
RATE OF CHANGE (SLOPE)

Circle the letter of each graph that shows a rate of change of 1.

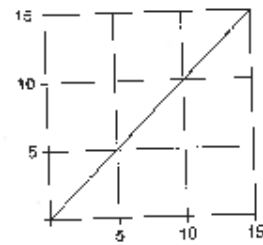
A.



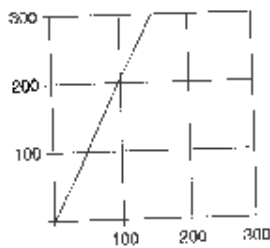
B.



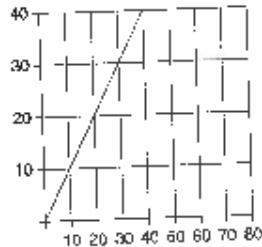
C.



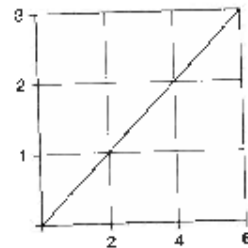
D.



E.



F.



Explain what helped you make your decision.

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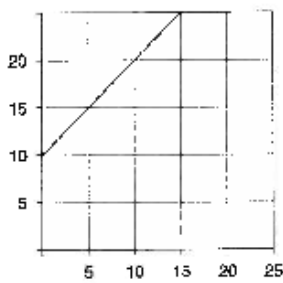
SLOPE II

VARIATION: RATE OF CHANGE (SLOPE) II

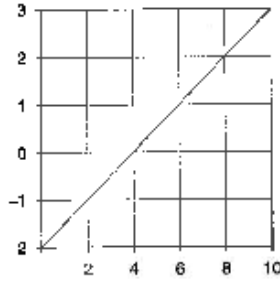


Circle the letter of each graph that shows a rate of change of 1.

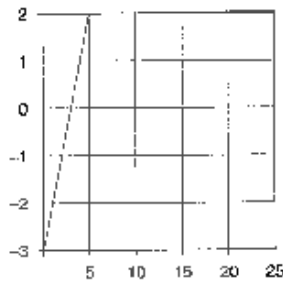
A.



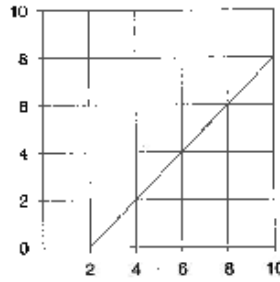
B.



C.



D.



Explain your reasoning for each.

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