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Advancement Of Understanding In Physical Science And Reduction Of Mathematical Anxiety Through The Use Of Supplemental Mathematics Material

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ADVANCEMENT OF UNDERSTANDING IN PHYSICAL SCIENCE AND REDUCTION OF MATHEMATICAL ANXIETY THROUGH THE USE OF SUPPLEMENTAL MATHEMATICS MATERIAL

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ABSTRACT

The purpose of this study was to determine if supplementary mathematics materials (created to be complementary to a physical science course) could provide a significant change in the attitudes and performance of the students involved. The supplementary text was provided in the form of a booklet. Participants were students in a physical science class.

Students were given surveys to evaluate existing knowledge of physical science, mathematics skill, and mathematics anxiety in the context of a science class. Students were divided into control and experimental groups by lab section, with the experimental group receiving a supplemental booklet. At the end of the semester, another anxiety survey was given. The anxiety surveys and test grades were compared between groups. Anxiety scores were compared between the beginning and end of the semester within each group.

Too few students reported using the booklets for a reliable statistical comparison (of grades) to be made. A statistically significant difference in mathematics anxiety levels was found between the groups.

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CHAPTER 1: INTRODUCTION

The quality and efficacy of Science, Technology, Engineering, and Mathematics (STEM) education in the United States of America is a matter of importance to the country (Larson-Freeman, 2013). The common goal is an increase in the number of scientists, engineers, and mathematicians that graduate in the United States.

The ability of a society to advance technologically is dependent upon that society's ability to educate their citizens adequately (Larsen-Freeman, 2013). This extends beyond the specific knowledge and skills imparted to students during their academic careers. The ability to adapt skills to new situations and apply knowledge to different contexts is extremely important. In her dissertation, Carter (2008) discusses the application of previously learned knowledge and skills to new circumstances. This process of adapting skills and knowledge has been debated for many years. The context within which learning takes place, the mental structures used, and the specificity of training have all been considered.

Buschman (2004) states that transferring understanding to a student is very difficult. The ability to solve new problems relies on the student's ability to transform their knowledge into a deeper understanding and then properly apply that understanding. Carter (2008) illustrates that there have been several methods utilized to increase the transference of knowledge and understanding. This study relies on the context in which information is presented.

Science and mathematics are the two primary disciplines of concern in this research. Berlin (2012) indicates that the two subjects are so deeply connected that they cannot successfully be explored separately. Research also suggests that the two subjects enhance each other (Hurley, 2001). Technology and engineering rely heavily on the understanding of science and mathematics, making this a matter of concern for STEM in general.

A matter of significant difficulty in the integration of math and science is that teachers do not always have the skills to teach problem solving abilities (Buschman, 2004). Neither have they experienced models of instruction which connect mathematics and science (Frykholm, 2005). This circumstance is further aggravated by the tendency of teachers - when under performance pressure - to revert to the teaching methods they experienced as students. High stakes testing is one source of performance pressure. According to work by Schmidt (2012) societal weakness in mathematics skills leads to an environment that inhibits the development of mathematics skills.

This research focused upon the inadequacies of preparation in mathematics education. The research explored the effects of mathematical understanding on performance in a science class. This quasi-experiment attempted to enhance the mathematical understanding of participants in order to determine the effect it had on scientific comprehension. Research indicates that anxiety in mathematics can also affect performance (Mohd, 2011). An understanding of mathematics is a component of performance in the physical science classroom. For this reason, there was also a component measuring the effect of the study on mathematical anxiety levels among students.

Statement of the Problem

The understanding of mathematics and science is important for academic success. Students have difficulties in learning mathematics and science due to algorithmic errors and content misconceptions (Li, 2008). Li (2008) asserts that the improvement of mathematics and science learning is complex and requires effort from multiple resources. The researcher has observed persistent misconceptions in the physical science classroom and laboratory.

Significance of the Study

One may consider the pursuit of a study of mathematics to be disconnected from the goals of a person in science education, but the two subject areas are deeply connected (American Association for the Advancement of Science, 1993 as discussed in Berlin, 2012). Mathematics is the language in which the ideas and principles of science is written and most purely expressed. It is the application to science in which mathematics obtains its fullest purpose and most noble effort. Any lacking in the mathematical preparation of a student will therefore imperil that student's science education. It is in the best interest of a science teacher, apropos mathematics, to ensure that their students demonstrate a high degree of proficiency. Studies (Anderson, 2012; Moseley, 2006; Ponce, 2004/2005) indicate that the connection of mathematics to other topics, especially science, provide an improved understanding of content and decreased anxiety toward the subject of mathematics. This naturally leads to higher performance and tends to improve the ability of students to transfer their academic pursuits into skills which are readily applicable to their “real world” lives.

By connecting science content to mathematical content, the science content can often be better understood. The mingling of the two subjects, even in a limited fashion, improves the comprehension and application of both. As mathematics is generally the prerequisite for scientific pursuit, this study will bring mathematics into a science context.

This research explored the unique approach of using a supplemental text in order to deliver the mathematical content within the context of a science classroom. This differs from other studies by not requiring a change in classroom instruction or a change in the textbook being used.

The interaction of content will be more fully explored under the subheadings "Interdependent Content", "Context of Content", and "Application of Knowledge" in the literature review to follow. The literature review will provide evidence to support the claim that student learning benefits from combining mathematics and science content in a single classroom setting. The literature review will also provide evidence that transfer of learning - which is the application of learning outside of the classroom or from one lesson to the next (Larsen-Freeman, 2013) - is improved through the combination of multiple subject areas.

It is common to find students with a debilitating mental connection to the field of mathematics (Ashcraft, 2001). Students suffer from a range of mild to severe mathematical anxiety - a feeling of panic, helplessness, paralysis and mental disorganization that arises among some people when they are required to solve a mathematical problem. Students have negative attitudes toward mathematics in the performance of tasks requiring the management of numbers (Nunez-Pena, 2013). Nunez-Pena indicates that anxiety related to mathematics can be a leading cause in a reduction of student performance as well as a reduced ability to transfer learning to new circumstances (2013).

Purpose of the Study

The purpose of this study was to determine if supplementary mathematics materials (created to be complementary to a physical science course) could provide a significant change in the attitudes and performance of the students involved. The supplementary text was provided in the form of a booklet. Booklets have already been proven as helpful tools to reinforce and increase learning in other studies (Brooke, 2012; Francis, 2013; Plow, 2014; Wilson, 2010).

This study may provide a benchmark for future work in the consideration of reworking textbooks, the production of new standards, and the future considerations of teacher education programs (especially those for secondary education). This component will be more thoroughly addressed in the "A Lack of Preparation" subheading in the literature review.

Hypotheses

Null Hypothesis One: There will not be a statistically significant difference in classroom test grades between the control and experimental groups.

Null Hypothesis Two: There will not be a statistically significant difference in the mathematical anxiety of participants in each group.

Overview of the Methodology

This study was designed as a quantitative study. One component addressed the academic performance of students. It depended on classroom test grades. The control and experimental groups were compared with independent t-tests. These t-tests used the scores from a mathematical skills pretest and a physical science pretest. This statistical analysis was used to determine if there was a statistically significant difference between the groups. The result allowed for the use of an independent t-test to determine if the test grade averages of the control and experimental groups had a statistically significant variance.

The other component was directed at the psychological effects of this intervention on the students. Data on anxiety was collected through the use of a Likert scale survey, completed at both the beginning and end of the study period. The survey scores were compared between the control and experimental groups (at the beginning and end of the semester) using a chi-squared test.

A survey on booklet usage was conducted at the end of the semester. The purpose of this survey was to determine when the booklet was used and what components were most used. This also presented an opportunity for participants to provide feedback.

The Supplemental Mathematics Booklet for Physical Science

The supplemental mathematics booklet was created to correspond directly to the physical science classroom and laboratory. The researcher applied his experience in lab instruction and classroom teaching - along with the consultation of other professionals - to create this booklet. This booklet has been designed to provide a review of the mathematical skills necessary not only in a physical science class but also in experiments in the physical science laboratory. Research from Hurly (2001) suggests that enhanced instruction is the form of integrated content which is most beneficial for science performance. Using a booklet allows research on enhanced instruction to be conducted without the need to alter current instruction.

The booklet was designed to be easily referenced. The arrangement of concepts was intended to build understanding in sequence. The sections of the supplemental booklet are: The International System of Units; Fractions, Decimals, and Percentages; Equations; Conversions; Graphs.

The section discussing The International System of Units (SI) is placed at the beginning of the document to be easily referenced. This system of measurements - also referred to as The Metric System - includes units, symbols, and prefixes with which students may be familiar. The SI is used throughout the semester.

The next section reviews fractions, decimals, and percentages. Multiplying or dividing one fraction by another is a skill that some students may not have mastered. If students do not have a firm understanding of manipulating fractions, they will be unable to grasp the manipulation of equations.

The relationship between fractions and decimals can be confusing for some students. Students will be required to convert between base units and those with prefixes – such as a conversion between grams and kilograms. Some students will memorize the relationship in terms of “moving the decimal” a certain number of spaces, in a certain direction. This provides for the possibility of erring in two avenues. Students will be unable to detect their error if they cannot discern that “moving the decimal” three spaces to the left is equivalent to multiplying by 1/1,000 or dividing the number by 1,000.

In the physical science laboratory, students are frequently required to compare their results to a standard amount. This is usually represented by a percent difference. Students will frequently create a proportional decimal number, then report this number as being a percentage. The fundamental understanding of the relationship between a proportion and a percentage is a necessary component of detecting this error and self-correcting. When interpreting results, a student reporting a 50% difference as a 0.5% difference will likely come to a highly erroneous conclusion.

The fourth section of the booklet discusses equations. Physics is dependent upon equations to express the fundamental relationships of the universe. Most of the concepts which are covered in the physical science classroom are related with the aid of the equations which express them. The relationships - when related in this way - can be clearly seen, provided a person can read an equation.

To apply an equation, a student should first isolate the variable they are seeking to define. This requires the manipulation of fractions, as previously reviewed in the booklet. While this may seem to be a negligible leap in skill, it is a difficult adjustment for some students. Another component of this process is the consideration of units. Units define the nature and scope of the numbers that are related. When units are included in the process of writing and solving an equation, they can provide feedback to the student. If the student is solving for velocity, the unit corresponding to the solution must be a velocity unit. When errant units are present, the equation was written or solved incorrectly.

The fifth section of the booklet discusses conversions. The process of converting between units is fundamental to physical science. Students are required to convert units (used by their measuring devices) into standard units. For example, a measurement in grams cannot be directly used to calculate force. A student must first convert grams to kilograms.

The final component of the booklet is a section reviewing graphs. Physical science concepts can often be related in the form of a graph. Graphs are often used as an alternative way of presenting the relationships found in physical science. A graph of position versus time can provide information related to velocity and acceleration.

Definitions

Enhanced integration - either science or mathematics is the major discipline of instruction, with the other discipline apparent throughout the instruction (Hurley, 2001).

Mathematical anxiety – a feeling of panic, helplessness, paralysis and mental disorganization that arises among some people when they are required to solve a mathematical problem; also negative attitudes toward mathematics in the performance of tasks requiring the management of numbers (Nunez-Pena, 2013).

Transfer of learning - the application of learning outside of the classroom or from one lesson to the next (Larsen-Freeman, 2013).

Limitations

This study did not account for student academic experience at the college level, in regard to the number of classes they have taken. This study did not track the majors, course-load, or work-load of students. There is not a record of interpersonal activity or organization participation. The study did not account for the interaction between the control and experimental groups outside of the laboratory or classroom setting.

The researcher was responsible for the lecture portion of two sections (of the course) as classroom instructor, but was not the laboratory instructor for those sections. The researcher was the laboratory instructor for a different section of the course. The researcher's laboratory section corresponded to another classroom instructor's lecture sections. The researcher also graded quizzes and tests for the other classroom instructor.

Delimitations

This study was intended to measure the effect of supplementary mathematics text on academic performance (in a physical science class) and mathematical anxiety - specifically if either could be positively impacted. The student population was limited to those who are enrolled in a specific university level physical science class at a university in the southeast of The United States of America. These students (traditionally) are not majoring in science or mathematics.

CHAPTER 2: LITERATURE REVIEW

This literature review presents evidence promoting the value of this research through a series of four supporting phases. The phases are: "A Lack of Preparation" in which the deficits of teacher preparation are discussed; "Interdependent Content" in which the interdependent nature of the subjects of mathematics and science are exposited; "Context of Content" in which the interdependent nature of the two subject areas is transitioned into the beneficial nature of combining multiple content areas in order to improve student learning; and "Application of Knowledge" in which the benefits of combining content areas to the transfer of student learning is discussed more fully.

A Lack of Preparation

The argument of combining science and mathematics content is fairly common. The application of this concept is less easily accomplished. Though it seems to be a practical and understandable goal, there are many difficulties in accomplishing the integration of the two fields - aside from those who simply have an intellectual objection to combining disciplines. These will be individually discussed in this segment of the literature review.

This phase will be discussing the lack of preparation for teachers in regards to content integration. This group includes individuals who teach grades k-12. A teacher that lacks experience in integrated instruction will have difficulty implementing it (Frykholm, 2005). Teachers are not the subject of this study, but are responsible for the previous education of the subject. The preparation of teachers is discussed in this literature review due to the impact teachers have on the research subjects.

The first and most directly obvious issue to consider is whether teachers are prepared to integrate material effectively in their classrooms. “Teachers need familiarity with instructional strategies and resources and access to resources - both human and material - to help reduce the planning time required and to make integrated instruction time more efficient and less difficult to manage” (Berlin, 2012, p. 28). This would seem to have a readily available solution. It requires additional training for teachers and administrators. Teachers are, after all, expected to be lifetime learners who hone their craft over time. There are workshops for the continuing education of teachers, as well as conferences full of seminars on a wide variety of topics. With all the differing levels of training, one might expect the problem to be solved in a few short years. This has not been the case. Teachers are not being asked to apply a creative twist to a lesson plan or to tweak their methodology in order to enhance performance. Teachers are receiving the request to fundamentally change the manner in which they execute their trade. This can be accomplished gradually - over a long period of time - but it is not a simple task. Further, it is not the only issue to be considered.

When mathematical skill is applied to a context - rather than being presented in a purely mathematical form - it moves to the much maligned territory of the “word problem” or “story problem.” This is not to say that students are unable to execute procedures in which they are instructed. Students are unable to interpret work in a critical way. One might respond to this difficulty with the suggestion that they be taught or trained in how to do so. Unfortunately, this crosses into a different issue. Buschman (2004) states that the NCTM standards ask teachers to “model for students problem-solving abilities that they neither possess nor have seen demonstrated by others" (Buschman, 2004, p. 306). In 2005, Frykholm indicated that "preservice teachers rarely experience as learners the type of instruction and professional responsibilities they are expected to perform once in the schools." Frykholm also states preservice teachers commented they felt pressured to connect science and mathematics, but had not frequently seen or experienced teaching that connected the two subjects (Frykholm, 2005, p. 139).

This entails that "the task of providing rich experiences for future teachers to develop prerequisite knowledge and experiences necessary for connected science and mathematics instruction continues to rest largely on the experiences provided within the context of the teacher preparation process" (Frykholm, 2005, p. 139). This issue must be addressed directly. "Unfortunately, a system of professional development on the scale required to affect significant change would be extraordinarily expensive, both in terms of money and time. Given current budgetary constraints, such an approach seems almost impossible" (Schmidt, 2012, p. 149). It is, therefore, not possible to readily aid those who are currently in the field to the extent which would be necessary.

Teachers aside, there are structural issues at work in making the integration of science and mathematics content a more difficult task. Berlin (2012) notes that "Recent literature related to teacher education and integrated science and mathematics education is less evident as standardized testing and accountability issues make content integration more challenging" (p. 21). This could be related to the stress and time constraints which are commonly associated with meeting achievement goals.

The structural issues are not limited to the faculty or testing requirements. Some point to the fundamental structure of the guidelines used to organize education. Collected data indicates the intended curriculum in the United States of America is "highly fragmented" and the implemented curriculum "exceptionally variable across and even within local education agencies" in comparison to higher performing countries (Schmidt, 2012, p. 133).

The complete reconstruction of the entire educational curriculum could be very time consuming and expensive. Reform is a necessary component of solving the problem of under-performance, but has significant cultural momentum working against it.

Schmidt (2012) notes that anxiety about the state of education in the United States of America results in support for more rigorous mathematical standards, but a lack of general skill dampens the effort to change (Schmidt, 2012, p. 152).

The literature reviewed in this component is currently lacking in a few areas, mostly concerning the teaching habits of teachers by comparison with their experience in integrated coursework. There was not a thorough set of research conducted specifically on new teachers in regards to their teaching habits and strategies corresponding to their experiences with integrated teaching at the university level. While this may be the result of a lack of emphasis on course content integration at the university level, some programs do exist. There has not (in the surveyed literature) been an investigation which compares teacher exposure to this teaching style and the frequency with which new teachers use integrated content lesson planning, activities, or assessments. The lack of research in this component reduces the knowledge of efficacy of content integration. Without knowing the retention aspect of integrative teaching methodology over traditional teaching methods, it is not possible to estimate the corresponding effects on student populations. This means the transmitted effect of the increased use of integrated content (at the university level) on teaching (at the public school level) cannot be directly correlated. It is not possible to eliminate the cumulative effect of other factors.

There is a similar lack of research content with relation to current in-service teachers. Their objectively measurable - not self-reported - exposure to integrative teaching methods can be reasonably estimated as being limited to additional coursework, teaching workshops, and conference participation. Although this likely has a much lesser effect on teaching habits, activities, and assessments: the research is still possible and remains to be performed. Without data on this aspect of the issue, the transformative capability of outreach to - and support of - current in-service teachers cannot be adequately measured. Without an adequate measurement of the effect of these various programs and activities, it is impossible to provide an accurate estimate of the investment of public resources necessary to assist current in-service teachers in advancing their teaching craft.

Interdependent Content

The interdependent nature of mathematics and science is readily apparent to those who pursue the field of science. There are arguments for the pursuit of pure mathematics - which will be elaborated upon in this section of the literature review. Material is provided to advocate for the combination of the two fields. The integration of the mathematics and science content areas is considered to be a more advantageous circumstance.

The literature indicates that the fields of mathematics and science are inextricably bound - "As stated in the *Benchmarks for Science Literacy* ... '... the ideas and practice of science, mathematics, and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from others'" (AAAS, 1993 as discussed in Berlin, 2012, p. 20). Admittedly, this is an opinion. The fact that the two content areas are related to each other does not necessitate their combination, but does encourage further exploration.

Mental state is a very important consideration for performance. As Mohd (2011) states, “there is significant relationship between attitude towards problem solving and mathematics achievement” (p. 53). As “patience towards problem solving is essential to achieve good results in mathematics. Based on the finding, it could be assumed that the level of patience plays an important role in mathematics achievement” (Mohd, 2011, p. 53).

There is also the specific function of mathematical anxiety. “Math anxiety disrupts the on-going, task-relevant activities of working memory, slowing down performance and degrading its accuracy” (Ashcraft, 2001, p. 236). Research from Nunez-Pena (2013) also indicates that mathematical anxiety has a negative correlation to mathematical performance.

Geist (2010) states that a negative view of mathematics could result in a smaller number of students choosing to take mathematics - or to take lower levels of mathematics - which could steer them away from higher education. Geist also notes that this is a major issue of concern for the economy and the future success of students. “Creating a country of 'mathophobes' does not bode well for us in the uncertain global economy of the future (Geist, 2010, p. 29).

Another study by Quinnell, Thompson, and LeBard indicates that mathematics anxiety has a negative impact on science performance at the undergraduate level. Their 2013 study demonstrates that instead of mathematical skills transferring across disciplines in a beneficial way, mathematical anxiety can be transferred and result in lower performance. “Maths anxiety is characterized by reports of feeling tense, apprehensive and fearful of maths [18] and results in a lower performance in maths-related situations and avoidance of such situations ... Maths anxiety disables learning in science” (Quinnell, 2013, p. 811).

This indicates the need to reduce anxiety related to mathematics. A study performed by Ponce (2004/2005) indicates that the integration of multiple subject areas - along with group participation in practicing problem solving strategies - can alleviate much of this stress. This study was performed with the combination of mathematics and language content through the use of “world problems,” but provides some hints to the use of other combinations.

Lack of comfort on the part of the teacher can be problematic in elementary and middle school grades, as teachers may not have extensive training in mathematics or science. A few studies show improvements to this specific group through the inclusion of mixed content classes during their undergraduate pursuits. “The results of the data analyses indicate that preservice teachers, regardless of certification area, clearly displayed positive attitudes and perceptions related to the value of the integration of mathematics, science, and technology education over all seven years of the program” (Berlin, 2012, p. 28). A study conducted by Mosley (2006) “suggests that a content course that emphasizes science and mathematics taken in conjunction with methods courses in mathematics and science can affect the teaching efficacies of preservice elementary teachers, particularly their belief in their influence on student outcomes” (p. 8). Again, this provides a solution for those teachers who will soon be entering the field, not for those already in the field.

Research indicates that the integration of mathematics and science is reciprocally beneficial in these content areas. Mathematics provides the tools to move science beyond observation and the rote memorization of facts. Science provides a context to mathematics which makes it both more relatable and more comprehensible to students. Sherrod (2009) states that the integration of mathematics into science activities will increase understanding of mathematics and demonstrate its usefulness. “When mathematics is incorporated into a science lesson, the two disciplines complement each other in such a way that the learning of both science and mathematics is enhanced (Sherrod, 2009, p. 249).

It is clear that the integration of mathematics and science is a valuable tool in the advancement of both fields. It is not easily or readily accomplished, but research indicates that this pursuit is worthwhile. It is a challenge worth accepting. Pang (2000) writes that the integration of mathematics into science is a challenging task, but the increase in open communication on the topic can help all students become more scientifically and mathematically literate (Pang, 2000).

There is a limited amount of available literature with regards to the integration of mathematics and science education at the high school and college levels. Hurley (2001) found only six studies with science outcomes and four studies with mathematics outcomes at the high school level. At the college level, Hurley found two studies with science outcomes and three with mathematical outcomes (Hurley, 2001).

The existing research indicates that enhanced instruction had a medium positive effect on science (Hurley, 2001). Elementary classes tend to have a designated group and teacher for all subjects. Being structured in this way requires a more rounded skill-set from teachers, but provides the opportunity to try different methodologies. This arrangement allows a single teacher to develop lesson plans for both required content areas without coordination with a second party. As the level of mathematics is lower, it may also provide greater comfort for the teacher in both the expression and transference of material in varying context.

Context of Content

Studies reviewed by Li (2008) attribute students' learning difficulties to an underdevelopment of logical thinking, lack of understanding of mathematical principles which generate the procedures they are asked to use, or a poor understanding of mathematics symbols. The students are lacking a unifying context within which to consider the sensibility of the use of mathematics skills they choose. This leads to the discussion of a central argument of this study. The context of a question is often as important as the question itself. Anderson (2012) relates that there has been a great deal of scrutiny directed towards traditional mathematics instruction - as an exposition of theories and principles for which it provides no application. They lack in the context which would allow them to be readily applied in the real world. Li (2008) suggests that the differences between mathematical and scientific concepts be noted when models are developed to explain students' misconceptions in school mathematics. Li's reasoning is "almost all mathematics concepts in numbers and algebra were constructed by mathematicians and thus have no concrete representations in daily life but abstract. In contrast, almost all school science concepts, such as heat, stem from students' lives" (Li, 2008, p. 6).

There are many subjects to which one's mathematical prowess may be applied. The comparison of unit price, analysis of interest rates, or the analysis of cost verses benefit. Even the adjustment of a recipe will be advanced if one is more skillful with fractions. With the need for both science and mathematics education, it seems logical to combine the two in order to accomplish a student's education more efficiently. This is in addition to the previously discussed reciprocal advantage to the learning in both content areas upon combination. Further, mathematics and science have often been (historically) paired because of their inherent relationship as content area disciplines. This connection is found in several professional organization recommendations, as well as with some early childhood teacher education programs. There are also several textbooks available which provide an interconnected mathematics and science content approach for these teacher education programs (Kalchman, 2012).

Applying mathematical skills to science activities - enhanced integration - increases a student's ability to apply what they have learned to various scenarios, much more so than lecture and formulaic practice. “When students sit passively in a classroom and endure the mere transmission of knowledge through didactic lecturing, they fail to construct an in-depth understanding. It is this comprehensive understanding that equips them to utilize their skills in the real-world” (Sherrod, 2009, p. 255). Students must practice in the use of their problem-solving abilities in order for transference of learning to take place more frequently.

“One way to help students develop higher order cognitive skills involves creating learning environments in which students can grow in their ability to reason and think, doing so within the context of the content and processes of science in a way that leads to solving real problems, decision making, and effective citizenship” (Journal of Chemical Education, 2004, p. 1533).

Another component which provides for advancement in the learning of mathematics and science is the reasoning benefit provided by a mixed content context. Ponce (2004/2005) performed a study in which children were asked to make corrections to sentences which were also a math question. This math question would need to be completed in order for the task to be completed. While it may initially seem that the combination of two challenging tasks would only lead to greater student confusion, the result was positive. The intent was that asking students to focus on the language in a question, they would read more carefully and thereby gain a better understanding of the mathematics. “The hope was that students would develop a habit of reading mathematics problems carefully before giving up on them all together” (Ponce, 2004/2005, p. 262).

This effort succeeded. By providing students with the task to first analyze and correct the language in which the question was asked, the content of the question was reinforced. The students were much more likely to complete the combined task without the need for exhaustive assistance than when the mathematics word-problem portion was independent.

For the STEM (Science, Technology, Engineering, and Mathematics) fields, the available research points to both the interdependence and beneficial relationship between these content areas. Becker (2011) notes that “The results revealed that integrative approaches among STEM subjects have a positive effect on the students' achievement. Based on the findings, further research and educational practice in STEM education are needed” (p. 31).

The available research in the area of contextual education is lacking in two primary components. The research is done on classes in which instruction is changed, with new activities and questions created for the purpose of having an integrated approach. This is a step which should eventually be taken. It is also the necessary pathway for advancing research with the younger students who were involved. This does not provide a direct comparison of exactly how much of the effect is resultant from providing a context for the material. It is possible that there are effects from previous activities (that contribute to student learning) that go unnoticed when mixed content is the only aspect considered. The proposed study alleviates this issue by maintaining instruction, assignments, and research assessments across both an experimental and control group. If the effect is different from the results of research in which instruction is changed, there may be other factors involved - an unwritten curricula that has gone unnoticed.

The second deficiency in the available research (discussed in this review) is the lack of independent effort among students participating in the studies. Students work in groups when performing tasks and undergoing inquiry of various processes. The extent to which advances in perceived student understanding are due to the contextual interconnection of mathematics and science are not clear - in comparison to the effect of group work. Research on independent effort is of particular interest as students move further into their academic careers. As students advance, they are expected to have greater responsibility for their understanding of material and to dedicate greater amounts of time outside of the classroom to increase their understanding and skill level.

Application of Knowledge

What is the purpose of requiring all citizens to receive education until reaching the age of legal adulthood? Instruction is motivated by the assumption that students can transfer their learning - apply what they have learned in school to another setting. A common problem arises when the expected transfer does not take place, what has been referred to as the inert knowledge problem. More than an academic inconvenience, the failure to transfer is a major problem, exacting individual and social costs (Larsen-Freeman, 2013, p. 107).

The applicability of education is crucial to the function of education. While knowing things is well and good, the function of a society requires that its citizenry is able make wise and informed decisions. This is dependent on the ability of the populace to either be informed or possess the ability to become so. As Larsen-Freeman (2013) indicates, when students leave their years of education without the ability to apply their knowledge, the cost to society can be dire.

While it may not seem that the skillful use of mathematics or the encyclopedic knowledge of many scientific properties and processes is fundamental to the daily lives of the average citizen, there is further advantage to this study than the increase of knowledge and skill. “The ability to think about, and reflect on, the problem-solving process is an important component of learning mathematics” (Thomas, 2006, p. 86).

What, then, is the solution to this quandary? Students are taught mathematics throughout their education, at least up to a minimum requirement of classes during their high school tenure. With that much experience in the subject, they must surely acquire the additional benefits of an education in mathematics. This is not necessarily true. Buschman (2004) says: “Problem solving requires understanding that goes beyond memorized facts and computation algorithms” (p. 305). Information must be transformed into usable knowledge before it can be used purposefully in problem solving (Buschman, 2004, p. 305). “Thus, problem solving must be taught as an integral part of mathematics learning, and it requires a significant commitment in the curriculum at every grade level and in every mathematical topic” (NCTM, 2012, p. 5).

The direct instruction of problem-solving - in addition to the mathematics content which must already be covered - could cause a great and unnecessary strain on teachers and students alike. This is more evidence of the advantage of an integrated content approach to science and mathematics. “Correlating and interrelating educational disciplines provides the opportunity for students to connect and apply what they learn in school to their everyday lives” (Rachford, 2011, p. 130). It is therefore important to find a way to integrate mathematics and science education at all levels of education. It would be best if this could be accomplished without the need to wait for standards and curriculum to be completely rewritten nationwide. It is also advantageous to neither require the attrition of the current teacher work force nor the exceedingly expensive and difficult process of retraining all of these professionals.

The available literature on research in the problem-solving ability of students is generally taken from mathematics classrooms and tested with application of mathematical ability. Enhanced integration through the injection of mathematical content into a science classroom will add to the diversity of information in this aspect.

Summary

The literature reviewed in this chapter indicates many advantages to the performance of this study. There is a lack in preparation of teachers (in the United States of America) for combining mathematical and scientific content (Frykholm, 2005). This is true of teachers currently undergoing their undergraduate teacher preparation, as well as those who are already in the classrooms. The effort to reform teacher preparation programs, as well as transition current classroom teachers to more integrated content, is a tremendous effort which will come with far extended time and expense. The course curriculum is also a problematic hurdle for the transition of integrated content - being designed without thorough consideration of the integration of scientific and mathematical content and their interdependent nature (Schmidt, 2012). This research provided a way around this issue by making integrated science and mathematical content directly available to the student, without the need to change current teaching conditions or assessments. Thus, further research into the field can be conducted without being nearly so limited in scope.

The literature indicates that mathematics education enhances problem-solving ability, and thus scientific applicability (NCTM, 2012), while the application of scientific context enhances mathematical ability (Sherrod, 2009). The integration of science and mathematics content enhances performance in both (Moseley, 2006). Studies indicating this depend upon integrated instruction. The advantage of this research project was that classroom instruction did not need to be changed.

CHAPTER 3: METHODOLOGY

The purpose of this study was to determine if supplementary mathematics materials could provide a significant change in the attitudes and performance of students enrolled in a physical science course.

Null Hypothesis One: There will not be a statistically significant difference in classroom test grades between the control and experimental groups.

Null Hypothesis Two: There will not be a statistically significant difference in the mathematical anxiety of participants in each group.

This study attempted to reduce the mathematical anxiety level of students through the use of the same material. The introduction of a supplementary mathematics content text was used as a method of enhanced integration. This text was in the form of a booklet. The booklet was designed to meet the mathematics content needs of physical science students in this study.

The general design of the study was quasi-experimental. Students were divided into a control or experimental group by lab sections. The experimental group was provided with the supplemental booklet at the beginning of the semester. The experimental group was introduced to the booklet during their first lab meeting. They were encouraged to use the booklet whenever it served to enhance their understanding of the current topic. The booklet also acted as a reference for mathematical procedures. The students in the experimental group were asked to keep a tally of each time they use the booklet, so that usage could be established at the end of the semester. They were also be surveyed on their usage of the booklet.

Quantitative Research

This study used quantitative research methods to study the 'transfer of learning' effects of supplemental texts. The study also used quantitative methods to study the effect that the supplemental booklets had on student mathematical anxiety levels. Creswell (2009, p. 4) describes quantitative research as "a means for testing objective theories by examining the relationship among variables. These variables, in turn, can be measured, typically on instruments, so that numbered data can be analyzed using statistical procedures."

The measure of academic performance chosen (by the researcher) for this study was the classroom test grades of students in the study. The researcher is familiar with the grading procedures used in the class. The classroom tests have been thoroughly examined and refined by the classroom teachers.

The researcher chose to use a Likert assessment of mathematical anxiety as a quantitative method of attaining data on this aspect. The researcher chose this method to reduce the scope of the mathematical anxiety component of the research. The mathematical anxiety data collected provided insight that could lead to further research, but did not require the extensive analysis of a more in-depth qualitative study.

A survey on booklet usage was conducted at the end of the semester. The survey asked participants if and when they used the booklet and the primary purpose for which they used it. The participants were asked how they perceived the booklet to have affected their understanding of the science content and mathematics content. The participants were also asked which sections were most useful. The final question on the survey requested feedback on what changes they would like to be made to the booklet, if another was made.

Researcher's Role

The researcher was a classroom instructor for two sections (of physical science) that have the same lecture time. The two sections indicated different lab times. The researcher was not the instructor for these lab sections. The other classroom instructor had several corresponding laboratory sections. The researcher was the laboratory instructor for one of these laboratory sections. This lab section was under the supervision of the other classroom instructor. The researcher met with the laboratory instructors (for all sections) on a weekly basis. A grading assessment process was used to compare the grading of all laboratory instructors to ensure grading was performed fairly across all sections. The researcher also graded student work for the other classroom instructor, under the other instructor's supervision.

The researcher conducted an initial assessment of student mathematics skill level using an assessment tool created by the researcher. It can be found in the appendix. This assessment was graded by the researcher. The researcher also conducted an initial assessment of student physical science knowledge. These assessments were used for the statistical comparison of the control and experimental groups. An independent t-test was used on initial assessment scores to determine if there was a statistically significant difference between the control and experimental group. These tests did not indicate a statistically significant difference between the control and experimental groups. An independent t-test was used to compare the classroom test grades of the control and experimental groups. The researcher was responsible for performing the statistical tests.

Research Bias

The researcher collected and analyzed data numerically. The researcher graded the initial mathematical skill assessment and the initial physical science knowledge assessment. A Likert scale attitudinal assessment was placed into a data table for statistical analysis.

Research Hypotheses

Null Hypothesis One: There will not be a statistically significant difference in classroom test grades between the control and experimental groups.

Null Hypothesis Two: There will not be a statistically significant difference in the mathematical anxiety of participants in each group.

Population and Sample

The population for this study was university students who were enrolled in a physical science course for non-science majors in the southeastern region of the United States. The sample was composed of students who were enrolled in sections of a physical science course in the spring semester of 2016. This population was selected because it represented students who were unlikely to be pursuing a mathematics or science intensive degree. This group was voluntarily enrolled in higher education - thus they were much more likely to seek higher achievement levels (Uyulgan, 2014). The selection of this population also provided a large sample size.

According to the website of the university from which the sample was taken, there is a gender distribution of 45% male to 55% female. In-state students make up 60% of the university’s population. It has a student to faculty ratio of 19:1. The student population at this university is 77% Caucasian, 13.4% African American, 3.8% Asian, 3.1% Hispanic, and 2.7% Other. The student retention rate is 86.5%, with an average ACT score of 24.7 and average GPA of 3.54.

The sample was composed of ten laboratory sections across three lecture periods. Two of the lecture periods contained approximately 70 students. The third contained approximately 30. The lab sections averaged a size of 16 students. The sample was 64% female with the control group being 71% female and the experimental group being 57% female. The students range in academic year, but are more often sophomores.

The students involved in the sample were divided into self-selected lab sections. Due to this sampling method, this study was quasi-experimental (Creswell, 2009). The participating sections were alternately control and experimental groups. These groups were indexed in a table once they had been formed. The experimental group was provided with a supplementary text booklet which contains mathematics tutorials that are related to their physical science course. The control group was not provided with a supplementary text.

Procedure

The study occurred over the course of the spring semester of 2016. The professor involved, as well as the lab instructors, had an information meeting before the study began. At the beginning of the semester, students in these sections were asked to participate in the study. At the first lab meeting, they were given the mathematics pretest, the physical science pretest, and the first mathematical anxiety survey. The researcher graded and recorded the scores of these assessments. The experimental group received their booklets at their first lab meeting. The booklets were attached to the inside of the lab manuals with adhesive. When students (in the experimental group) had a question that was addressed by the booklet, lab instructors encouraged the students to use it. They then received informal assistance from the lab instructor, as necessary. Students in the control group received informal assistance from the lab instructor without additional supplementary material.

At the end of the semester, students were given their second Likert scale assessment for mathematical anxiety. The experimental group were also be given a survey regarding their usage of the booklets. The survey of booklet usage had a component allowing for student feedback.

The initial mathematical anxiety (Likert scale) surveys were compared between groups with a chi-squared test. The final anxiety survey results were also compared using a chi-squared test. The surveys were also paired by student name for richer data collection. The names are not published.

The researcher used the scores from physical science pretests and mathematics pretests in independent t-tests comparing the control and experimental groups. These t-tests did not show a statistically significant difference between the groups. Independent t-test were used to compare the classroom test grades between the control and experimental groups. The researcher compared the results to the supplemental text booklet usage data.

The researcher used the booklet survey to identify the number of participants who used the booklet in each section. This number was recorded (by section) along with the number of participants who reported not using the booklet. The researcher also recorded responses to the other questions on the survey - grouping them into categories.

Instruments

This research quasi-experiment used several instruments. One instrument was a Likert scale survey of mathematical anxiety. This assessment tool was created by the researcher and was checked for validity by a college professor with a degree in education, as well as two mathematics professors. A pilot study was conducted to confirm the reliability of this assessment. The pilot study used college students as the sample. A dependent t-test (with a 0.05

alpha value) indicated no statistically significant difference in the first and second trials of this assessment.

The mathematics assessment is a pretest created by the researcher. This assessment was reviewed by two mathematics professors to ensure validity. Again, a pilot study was conducted to confirm the reliability of this assessment, using college students as the sample. A dependent t-test (with a 0.05 alpha value) indicated no statistically significant difference in the first and second trials of this assessment.

The physical science assessment is a pretest created by the researcher, who is an adjunct professor of physical science. The assessment was reviewed by another physical science professor to ensure validity and reliability. The booklet usage survey was also created by the researcher.

Data Collection

This study was quantitative. The students were assessed in two ways. One assessment was student classroom numerical grades - compared between the control and experimental groups. Classroom grades were selected due to the thorough nature of this collection method. The comparison of these grades provides a performance evaluation to assess the academic impact of the use of a supplemental text booklet corresponding to the course. The second assessment tool was a Likert scale instrument, which recorded the students' mathematical anxiety at the beginning and end of the study. This instrument can be found in the Appendix.

During the first lab meeting of the semester, students were informed of the research study. They were then presented with the consent documents, mathematical skills pretest, physical science pretest, and initial mathematical anxiety assessment.

Over the course of the semester, the classroom test grades were collected. The test grades on finals were not included. Some students chose not to participate in the research. Their grades were removed.

Participants were given the final mathematical anxiety survey at the last lab meeting (not including the lab final). The experimental group was also given the booklet usage survey - to collect usage data and feedback - at this meeting. This survey can also be found in the appendix.

Data Analysis

The control and experimental groups were compared with independent t-tests. These t-tests used the scores from a mathematical skills pretest and a physical science pretest. This statistical analysis found no significance between the groups. An independent t-test was used to determine if the classroom test grades had statistically significant variance between groups.

The null hypothesis for this test was that there was no significant difference in the grades of the control and experimental groups. If this null hypothesis was rejected, the science context booklet will have been the cause of a statistically significant difference between the two groups.

The Likert scale surveys were compared (by group) using a chi-squared test. The initial surveys were compared between the control and experimental groups. This was also done with the final surveys. The initial and final surveys (for each group) were compared as well. The anxiety surveys were also paired by student. The differences between initial and final scores were recorded for each student without the student's name attached. These differences in scores have been averaged for each section.

The responses on the booklet usage survey were recorded and categorized. The number of students who reported using the booklet in each section, compared to the number who reported not using it, was recorded. Responses to the other items on the survey were recorded by category for reporting.

Some students had data removed from the analysis. Three students chose to not participate in the study - on male and two females. Due to incomplete collection, 24 participants had data removed from statistical testing. There was an even mix of genders in this group. Ten of these participants left the class. Fourteen did not take the final anxiety survey.

Documents

The documents that were collected during this research study will be kept in a secure location. At the conclusion of the study, they were sealed in a box. They will be stored in a secure location for five years, before being destroyed.

Ethical Considerations

The researcher obtained permission from the university's Institutional Review Board (IRB) before beginning the research study. The researcher has completed Collaborative IRB Training Initiative (CITI) Course in the Protection of Human Research Subjects as required by the university's IRB. Students were given information letters regarding their participation in this study. The names of student participants were not presented in the results of this research.

Internal Validity

This study was quantitative and relied upon the process and results of statistical analysis for its credibility. To confirm validity, the mathematics pretest was created with the consultation of two mathematics professors. It was then tested through a pilot study to analyze its reliability. Volunteers were given the assessment on two separate dates, no less than two weeks apart. The assessments were then graded by the researcher. A dependent t-test (with a 0.05 alpha value) of the mathematics assessment tool scores indicated that there was no statistically significant difference between the initial and final trials of the paired test.

The booklet was created specifically for this study. It has been evaluated by physical science instructors to confirm that it corresponds to the content of the class and laboratory for which it will be used.

The Likert scale assessment was created for this research. It was analyzed by an education professor and two mathematics professors to confirm its validity. A pilot study was conducted - with the assistance of college student volunteers - to confirm its reliability. Volunteers were given the assessment on two separate dates, no less than two weeks apart. A dependent t-test of the responses to this assessment indicated that there was no statistically significant difference between the first and second trials of the paired survey groups. An alpha value of 0.05 was used for both statistical analyses.

In order to avoid the diffusion of treatment - the effect of communication between the groups (Creswell, 2009, p. 163) - the participants were divided by lab section. Time in lab was the primary time period in which students in the study were together and able to communicate. Mortality of participants was compensated by a large sample size.

The population for this study was university students who were in a physical science course in the southeastern region of the United States of America. The researcher does not claim generalizability (of the results of this study) outside of this population. This study used a large sample from a university in the southeastern region of the United States of America to represent this population.

Summary

This was a quasi-experimental quantitative study. It attempted to determine if a supplemental mathematics booklet could improve the performance of physical science students, as measured by their classroom test grades. It also attempted to determine if this supplemental text would reduce the mathematical anxiety of students.

The population for this study was composed of students in the southeastern region of the United States of America who were enrolled in a physical science course. The sample was composed of physical science students at a university in the southeastern region of the United States of America.

A mathematical skills pretest and a physical science pretest were given to the participating students at their first lab meeting of the semester. They were also given a Likert scale mathematical anxiety assessment survey at this point. The students were given the same mathematical anxiety survey at their final lab meeting of the semester. The students were divided into experimental and control groups based upon the laboratory section in which they had enrolled. Students in the experimental group were given a supplemental mathematics booklet that was created to be complementary to their physical science course.

At the end of the semester, the collected data was analyzed. The mathematical and physical science pretests were used to determine if there was a statistically significant difference in ability between groups.   A chi-squared test compared the scores on the initial survey between the control and experimental groups. It was also used to compare the control and experimental groups on the final anxiety survey. A booklet usage survey was given to the experimental group to determine if and when they used the booklet. This survey was also used to collect feedback on their impressions of its content and effects.

CHAPTER 4: RESULTS

The purpose of this study was to determine if supplementary mathematics materials (created to be complementary to a physical science course) could provide a significant change in the attitudes and performance of the students involved. The supplementary text was provided in the form of a booklet. Booklets have already been proven as helpful tools to reinforce and increase learning in other studies (Brooke, 2012; Francis, 2013; Plow, 2014; Wilson, 2010). This study focused on the effects of enhancing science instruction with mathematical support. Research indicates that the integration of science and mathematics content enhances performance in both subjects (Moseley, 2006). The null hypotheses of this research were:

Null Hypothesis One: There will not be a statistically significant difference in classroom test grades between the control and experimental groups.

Null Hypothesis Two: There will not be a statistically significant difference in the mathematical anxiety of participants in each group.

Data Analysis

The mathematical skills pretests (for participating students) were graded by the researcher. Each item on the mathematical skills pretest was given a value of two points. One point was awarded for demonstrating a procedure that would result in a correct answer. Two points were awarded if the answer was correct. The total possible score for the mathematical skills pretest is 16. The mean score for each group is included in table 1. These scores were then collected into the control and experimental groups. An independent t-test was used to compare the control and experimental groups, using an alpha value of 0.05. The results of this test indicated no statistically significant difference between the groups. These results can be found below, in table one.

Table 1: t-Test Results for Mathematics Skill Pretest

Control		Experimental			
Mean	*n*	*Mean*	*n*	*t Critical*	*t*
12.65	105	11.92	102	1.97	1.59

The physical science pretests (for participating students) were graded by the researcher. Each item on the physical science pretest was given a value of one point. The total possible score for the physical science pretest is 10. The mean score for each group is included in table two. These scores were then collected into the control and experimental groups. An independent t-test was used to compare the control and experimental groups, using an alpha value of 0.05. The results of this test indicated no statistically significant difference between the groups. These results can be found below, on table two.

Table 2: t-Test Results for Physical Science Pretest

Control		Experimental			
Mean	*n*	*Mean*	*n*	*t Critical*	*t*
12.65	105	11.92	102	1.97	1.59

The initial and final mathematical anxiety surveys were recorded by the researcher. Scores were paired by student and collected into tables by section. The averages for each question, by group, were calculated. These results can be found below in table three.

Table 3: Average Responses to Mathematical Anxiety Survey

Rated from 1 (strongly disagree) to 5 (strongly agree).

	Control		Exp.	
Statement	*Initial*	*Final*	*Initial*	*Final*
Solving math "word problems" does not make me nervous.	3.4	3.3	3.2	3.5
I am confident in my ability to use algebra.	3.9	3.6	3.7	3.9
I can use math for everyday needs without feeling confused.	4.0	3.9	3.9	4.1
I feel that my mathematics performance on tests represents my ability.	3.5	3.3	3.3	3.6
When I think of completing an assignment for science class, I feel comfortable with the level of challenge and my mathematical ability to complete the assignment.	3.5	3.5	3.4	3.6

The average difference in scores - between the initial and final surveys - can be found in table four.

Table 4: Anxiety Survey Difference (Initial to Final) by Section

Control Section Difference

Statement	1	2	3	4	5
1	-0.13	0	-0.22	-0.24	0.06
2	-0.33	-0.15	-0.39	-0.29	0
3	0.13	0.15	-0.33	-0.24	-0.24
4	-0.27	-0.4	-0.22	-0.33	0.29
5	-0.13	0.1	0.05	-0.29	0.47

Experimental Section Difference

	1	2	3	4	5
1	0.35	0.42	-0.18	0.26	0.25
2	0	0.16	0.31	0.32	0.13
3	0.2	0.26	0.18	0.21	0
4	0.3	0.68	0	0.21	0.31
5	0.4	0.63	-0.13	-0.32	0.06

The initial Likert scale surveys were compared between the control and experimental group using a chi-squared test. This was also done with the final Likert scale surveys. The chi-values and p-values are recorded in table five. The critical value for this test was 9.48. An alpha value of 0.05 was used. Two items on the initial survey were found to be statistically significantly different. The first was statement one: “Solving math ‘word problems’ does not make me nervous.” The experimental groups’ responses indicated greater disagreement with this statement.

Table 5: Chi-Squared Test Results

Statement	Initial		Final	
	p	chi	P	chi
1	0.003206	15.86481	0.80888	1.59951
2	0.105523	7.644048	0.084747	8.193333
3	0.096549	7.867647	0.131423	7.085799
4	0.000237	21.63057	0.053841	9.308205
5	0.897851	1.07734	0.656352	2.434778

The second item was statement four: “I feel that my mathematics performance on tests represents my ability.” The response counts on this item are listed below in table six.

Table 6: Statement 4 of Initial Survey

Response	Control	Experimental
1	5	13
2	13	8
3	21	28
4	33	21
5	19	21

The scores on the initial and final Likert scale surveys were compared - using the same chi-squared test - for both the control and experimental groups.

Responses to statements two and four were found to have changed significantly from the initial to final surveys for the control group. When comparing the final survey to the initial survey, students in the control group responded more positively ($p = 0.040$) to the statement: “I am confident in my ability to use algebra.” Students in the control group responded more negatively ($p = 0.031$) to the statement: “I feel that my mathematics performance on tests represents my ability.”

When comparing the final survey to the initial survey, students in the experimental group responded more positively ($p = 0.017$) to the statement: “I feel that my mathematics performance on tests represents my ability.”

Independent t-tests were used to determine if the classroom test grades had statistically significant variance between groups. The null hypothesis for this test was that there was no significant difference in the grades of the control and experimental groups. The results can be found below in tables seven, eight, nine, and 10. The t-tests indicated no statistically significant difference between the control and experimental groups. Table seven contains the results from the t-test conducted using the grades from test one. The results of this test indicate no significant difference between the control and experimental group's grades on this test.

Table 7: t-Test Results for Classroom Test One

Control		Experimental			
Mean	*n*	*Mean*	*n*	*t Critical*	*t*
78.16	108	79.16	107	1.97	-0.44

Table eight contains the results from the t-test conducted using the grades from test two. The results of this test indicate no significant difference between the control and experimental group's grades on this test.

Table 8: t-Test Results for Classroom Test Two

Control		Experimental			
Mean	*n*	*Mean*	*n*	*t Critical*	*t*
83.41	102	80.88	105	1.97	1.59

Table nine contains the results from the t-test conducted using the grades from test three. The results of this test indicate no significant difference between the control and experimental group's grades on this test.

Table 9: t-Test Results for Classroom Test Three

Control		Experimental			
Mean	*n*	*Mean*	*n*	*t Critical*	*t*
76.69	102	74.36	105	1.97	0.95

Table ten contains the results from the t-test conducted using the grades from test four. The results of this test indicate no significant difference between the control and experimental group's grades on this test.

Table 10: t-Test Results for Classroom Test Four

Control		Experimental			
Mean	*n*	*Mean*	*n*	*t Critical*	*t*
75.61	103	71.96	105	1.97	1.63

A statistical analysis was performed using the scores of those who used the booklet. Their scores on the physical science and mathematical skills pretests were compared to the control group using independent t-tests. The pretests found no statistically significant difference between the two groups. The results for the physical science pretest are included in table 11. The results of this test indicate no significant difference between the control and experimental group's grades on this test.

Table 11: Physical Science Pretest for Booklet Users

Control		*Users*			
Mean	*n*	*Mean*	*n*	*t Critical*	*t*
5.87	*105*	*6*	*14*	*2.11*	*-.025*

The results for the mathematics skills pretest are included in table 12. The results of this test indicate no significant difference between the control and experimental group's grades on this test.

Table 12: Mathematics Skills Pretest for Booklet Users

Control		*Users*			
Mean	*n*	*Mean*	*n*	*t Critical*	*t*
12.65	*105*	*13.77*	*13*	*2.10*	*-1.64*

Independent t-test were used to compare the test grades of those who used the booklet to the control group. The use of an independent t-test is not considered appropriate for a sample of this size, as the test does not work. It has been added to provide the reader with more information, but is not meant to imply a valid statistical comparison. The results for test one are included below in table 13.

Table 13: Booklet Users t-Test for Test One

Control		*Users*	

Mean	*n*	*Mean*	*n*	*t Critical*	*t*
78.16	*108*	*81.79*	*14*	*2.12*	*-0.85*

The results for the t-test of booklet users for test two are included in table 14. The results of this test indicate no significant difference between the control and experimental group's grades on this test.

Table 14: Booklet Users t-Test for Test Two

Control		*Users*			
Mean	*n*	*Mean*	*n*	*t Critical*	*t*
83.41	*102*	*83.92*	*13*	*2.14*	*-0.14*

The results for the t-test of booklet users for test three are included in table 15. The results of this test indicate no significant difference between the control and experimental group's grades on this test.

Table 15: Booklet Users t-Test for Test Three

Control		*Users*			
Mean	*n*	*Mean*	*n*	*t Critical*	*t*
76.68	*102*	*72.64*	*14*	*2.14*	*0.60*

The results for the t-test of booklet users for test four are included in table 16. The results of this test indicate no significant difference between the control and experimental group's grades on this test.

Table 16: Booklet Users t-Test for Test Four

Control		*Users*			
Mean	*n*	*Mean*	*n*	*t Critical*	*t*
75.61	*103*	*73.86*	*14*	*2.12*	*0.53*

The results for the t-tests comparing those who used the booklet to the control group indicate that the booklet did not have a statistically significant effect on academic performance.

The average responses to the mathematical anxiety surveys were calculated for those who reported using the booklet. These results are recorded below in table 17.

Table 17: Average Mathematical Anxiety Survey Responses with Users

Rated from 1 (strongly disagree) to 5 (strongly agree).

	Control		Users	
Statement	*Initial*	*Final*	*Initial*	*Final*
Solving math "word problems" does not make me nervous.	3.4	3.3	3.3	3.5
I am confident in my ability to use algebra.	3.9	3.6	4	4.4
I can use math for everyday needs without feeling confused.	4.0	3.9	4.1	4.4
I feel that my mathematics performance on tests represents my ability.	3.5	3.3	3.3	3.9
When I think of completing an assignment for science class, I feel comfortable with the level of challenge and my mathematical ability to complete the assignment.	3.5	3.5	3.4	3.6

Booklet Data

Discussions with laboratory instructors indicated high usage of the supplementary mathematics booklets (by students) at the beginning of the semester. The lab instructors also related the usefulness of the booklets as a teaching tool.

Students in the experimental group were given a booklet usage survey - found in the appendix - to assess their use of the booklets and offer an opportunity for the students to provide feedback. The first question on the survey asked if the student had used the booklet and when. Fourteen of the ninety-three experimental group participants indicated that they had used the booklet. Eight of these students were in a section (of 20) together. This section's pretest grades and classroom test grades were compared to the control group. The section was not found to have a statistically significant difference in scores on the pretests. The t-test of classroom test two indicated a statistically significant difference between this section and the control group.

The result of this test was a t-statistic of 2.37 and (two-tail) p-value of 0.02. The alpha value for this test was 0.05 and the two tail critical value 2.04.

Question one of the booklet usage survey instructed those who did not use the booklet to proceed to question six, which asked "Which sections were particularly helpful?" Nine of the students who indicated not using the booklet responded to this question. The responses indicated the key terms section, graph section, math section, and all sections. Two respondents indicated finding the section on units particularly helpful. Three respondents found the conversion section helpful. Feedback from students indicated that the booklet was not used because they had either forgotten about having it or felt that they didn't need it. Some of those students (reporting they didn't need the booklet) were high performers. Others stated that laboratory instructor intervention precluded the need for the booklet.

The responses of those who reported using the notebook were recorded and grouped by the researcher. The second part of question one, asking when the booklet was used, indicated greatest use during the early part or beginning of the semester. The content of the early portion of the semester includes learning to make unit conversions and to present numbers in correct notation. This skillset is used for the entire semester.

Question two: "What did you primarily use the booklet for?" The majority of responses to this question indicated that the conversion section of the booklet was most heavily used. This section demonstrates the process of changing a figure in one unit, (such as pounds) into another equivalent unit, (such as newtons). Other responses included equations, definitions, and formulas.

Question three: "In what ways did the booklet affect your understanding of the mathematics related to physical science?" The majority of responses to this question again referenced conversions. One respondent noted that it "helped science by helping math." Other responses included using the booklet as a quick reference and gaining a better "visual understanding."

Question four: "How did the booklet affect your understanding of the mathematics related to physical science?" The majority of responses indicated that the booklet aided in the understanding of conversions. This responses was closely followed by a statement indicating that the booklet was helpful. The remaining responses indicated that the booklet helped more with math than science, and that it helped with formulas, measurements, and to "jog" memory.

Question five: "which sections were particularly helpful?" The overwhelming majority of responses to this question indicated that the section on conversions was found to be most helpful. This was followed by the section on equations and measurements. The other responses fractions, formulas, unit prefixes, definitions, and graphs.

Question six: "If a new booklet were to be made, what would you want to be changed? You may also add any feedback you would like to provide." The majority of respondents indicated they would not change the booklet. This was closely followed by a request to make the booklet fit each experiment. Others asked for more terms, better formatting, a shorter booklet with less information, more conversions, and a change in wording.

Summary

The control and experimental groups were given a mathematical skills pretest, a physical science pretest, and the initial mathematical anxiety assessment. Those in the experimental group were given the supplemental mathematics booklet. At the last lab meeting of the semester, participants were given the final mathematical anxiety assessment. Those in the experimental group were given a survey on booklet usage.

The mathematical anxiety survey responses were compared between groups. A chi-squared test of the initial mathematical anxiety survey indicated a statistically significant difference between the control and experimental groups for statements one and four. The experimental group indicated more disagreement with the statement: “Solving math ‘word problems’ does not make me nervous.” The responses to statement four indicated a broader spread of agreement or disagreement with feeling that test performance was indicative of ability.

The researcher conducted independent t-tests using the mathematical skills pretests and physical science pretests. The result of these tests indicated no statistically significant difference between the control and experimental groups.

The four classroom test grades for each group were compared using independent t-tests. The results of these test indicated no statistically significant difference between the control and experimental groups.

The booklet usage survey indicated that only 14 of 93 respondents had used the booklet. Eight of these respondents were in one section of the course.

The statistical tests were repeated with those who reported using the booklet compared to the control group. These results indicated no statistically significant difference between those who used the booklet and those in the control group.

The survey also indicated that the booklet portion found to be most useful was the section detailing unit conversions. Feedback on possible changes to the booklet indicated that a closer tailoring to individual experiments was favored.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

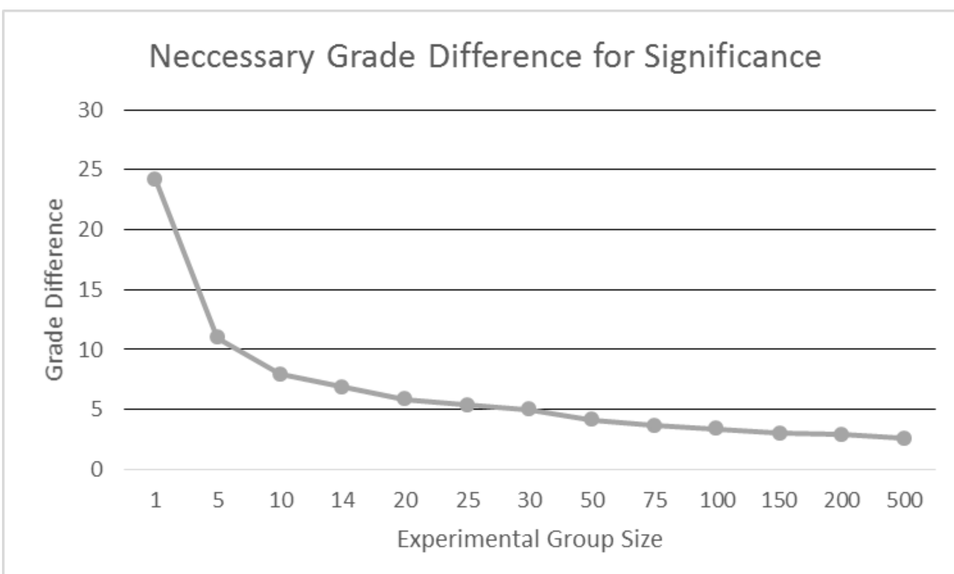
The purpose of this study was to determine if supplementary mathematics materials (created to be complementary to a physical science course) could provide a significant change in the attitudes and performance of the students involved. The null hypotheses used in this experiment were that there "will not be a statistically significant difference in classroom test grades between the control and experimental groups" and that there "will not be a statistically significant difference in the mathematical anxiety of participants in each group."

This research used a supplementary text as a way to introduce mathematical content into a physical science classroom. The aim of this introduction was to provide the advantages of enhanced integration to the experimental group of students without having to alter the course as a whole. The increased performance and improved transfer of learning were intended to be measured through classroom test grades. Mathematical anxiety surveys were also conducted to determine if there was an effect on mathematics related anxiety in the experimental group. Chi-squared tests were performed on the initial and final surveys to determine if there was a statistically significant difference between the two groups - or between the initial and final surveys for each group - on each statement of the assessment.

The responses to the booklet usage survey indicate that only a very small portion of students (14 of 93) used the booklet. This is contradictory to discussions with laboratory instructors, who reported high usage at the beginning of the semester. Although the test does not work for a sample size this small, independent t-tests were used to compare the classroom grades of those who used the booklet to the classroom grades of the control group and found no statistically significant difference. The group that reported using the booklet was 64% female. The control group users were 71% female and the experimental group users were 57% female.

The low number of reported booklet users makes an accurate analysis of the booklet's effects impossible to do with a t-test. If the independent t-test were to work for small samples, the effect size would still need to be comparably large to be statistically significant. A graph is included below, (figure 1) to demonstrate the necessary mean grade difference to see a statistically significant result. This was accomplished using the group size (n_2 = 102) from this research's control group. An alpha value of 0.05 and a t-critical value of 1.98 were also used with an assumed equal variance. The independent t-test formula was reorganized to provide the needed difference in grade means for the given group sizes.

Figure 1



Analysis comparing the initial and final mathematical anxiety survey showed - among the experimental group - a positive change in the feeling of having mathematics performance on tests match student ability. Participants in the control group displayed a negative change on this item. This may be a reflection of Ponce's (2004/2005) findings that the combination of subjects can reduce stress related to problem solving. Ponce also found that students were likely to engage in multi-subject questions more thoroughly.

Mohd (2011) indicates attitude toward problem-solving has a significant relationship with achievement. Expanding on the effect (seen in this study) may result in a statistically significant academic gain.

Hurley (2001) found enhanced integration to have a positive effect on science achievement. The same effect should reasonably be expected in this research. If the booklet feedback is accurate, the booklets were not (widely) used and therefore could have little effect. This will be addressed in the recommendations.

Recommendations

Low reported usage indicates that measures should be taken to ensure a higher percentage of booklet use by experimental participants. Feedback from participants indicated that many students failed to use the booklet because they had forgotten about it. Some also indicated that they did not need the booklet. Some of the students indicating they did not need the booklet were high-performing. Others indicated not needing the booklet due to laboratory instructor intervention.

The researcher recommends that participant feedback be implemented by making the booklet more thoroughly integrated into the laboratory procedure. Students indicated that they desired the booklet to correspond to each experiment individually. An index of sections applying to each laboratory experiment may be helpful. The researcher recommends that each laboratory experiment should have corresponding booklet sections listed.

Further integration of mathematics into the laboratory procedure may increase effectiveness as well. The researcher recommends that mathematics questions (related to the laboratory procedure and booklet) be added to the laboratory quizzes.

Students reported a higher rate of use of the booklet (and a greater positive effect) at the beginning of the semester. The material covered at the beginning of the semester, including unit conversion and significant figures, is used for the remainder of the semester. The researcher recommends that a greater emphasis be placed on prompting students to use the booklet in the first several labs. This may be best approached by addressing the use of the booklet during the introduction of that day's laboratory procedure. The researcher also recommends that the booklet be used as a bookmark for the lab manual, rather than securing it at the end of the lab manual. This will act as a continual physical reminder to students that they have the booklet as a reference.

The number of students who reported using the booklet was not large enough to analyze with an independent t-test. Without this data, efficacy of the booklet is not readily determinable. Feedback provided by students indicates that more examples - and greater variety in types of examples - would be helpful. The researcher recommends the booklet be expanded to include two to three examples of each concept.

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APPENDIX

APPENDIX A: CONSENT FORM

Consent to Participate in Research

Study Title: Advancement of Understanding in Physical Science and Reduction of Mathematical Anxiety Through the Use of Supplemental Mathematics Material

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☐ By checking this box I certify that I am 18 years of age or older.

The purpose of this study

This is an experimental study for performance in physical science and for mathematics anxiety as related to physical science. We wish to determine if supplemental material alone can be of benefit to academic performance or anxiety reduction in the physical science class. Some participants will be provided with written material in addition to other classroom and laboratory material while the “control group” will not. All students will receive the full support of instructional faculty and staff.

What you will do for this study

There are three phases to this study in which you will be participating.

1. You will be given a series of preliminary assessments that be used as a baseline for statistical analysis. These include:
    a) a physical science pretest to assess your general content knowledge
    b) a college algebra pretest to assess your general mathematical skill
    c) a mathematics anxiety survey to gauge your general anxiety toward mathematics in the context of a physical science class
2. You will be assigned to the “experimental group” or the “control group” based upon the laboratory section in which you have enrolled.
3. You will proceed through the semester as normal. The “experimental group” will use supplemental material in addition to other classroom material. This will mostly be addressed during lab.
4. At the end of the semester, you will complete the mathematical anxiety survey again. Those students in the “experimental group” will also complete a short survey on their use of the

supplementary material.

Time required for this study

The initial pretests and surveys may take up to 30 minutes during the first lab meeting. The second administration of surveys may take up to ten minutes of lab time.

Possible risks from your participation

There are no risks involved in participation in this research.

Benefits from your participation

Participation of the experimental group in this study may result in better academic performance in the physical science class. Participation by the experimental group may also reduce math-related anxiety in the context of physical science.

Incentives

You will receive no direct incentives for your participation.

Confidentiality

1. The researcher (James C. Roberson) is the only person who will have access to your data and/or responses. The researcher also has access to your grades (in this class) and will be using them for statistical comparison. This data will be coded such that only the researcher can link your responses, scores, and/or grades to you. The encoding mechanism will be kept totally separate from the data that will be used for the study. All original documents will be kept sealed until they are destroyed at a later date.
2. The committee responsible for reviewing the ethics of, approving, and monitoring all research with humans – has authority to access all records. However, the IRB will request identifiers only in special cases.
3. We will not release identifiable results of the study to anyone else without your written consent unless required by law.

Alternative Assistance

There are alternative supplements to the one provided. Participants may find similar material through web-searches and library research. Such material may be listed as applied mathematics in science.

Right to Withdraw

You do not have to volunteer for this study, and there is no penalty if you refuse. If you start the study and decide that you do not want to finish, just tell the experimenter. Whether or not you participate or withdraw will not affect your current or future relationship with the Department of

Physics and Astronomy, or with the University, and it will not cause you to lose any benefits to which you are entitled.

Student Participants in Investigators' Classes

Special human research subject protections apply where there is any possibility of coercion – such as for students in classes of investigators. Investigators can recruit from their classes but only by providing information on availability of studies. They can encourage you to participate, but they cannot exert any coercive pressure for you to do so. Therefore, if you experience any coercion from your instructor, you should contact the IRB via phone (662-915-7482) or email (irb@olemiss.edu) and report the specific form of coercion. You will remain anonymous in an investigation.

IRB Approval

This study has been reviewed by The University of Mississippi's Institutional Review Board (IRB). The IRB has determined that this study fulfills the human research subject protections obligations required by state and federal law and University policies. If you have any questions, concerns, or reports regarding your rights as a participant of research, please contact the IRB at (662) 915-7482.

Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, you can decide if you want to be in the study or not.

Statement of Consent

I have read the above information. I have been given a copy of this form. I have had an opportunity to ask questions, and I have received answers. I consent to participate in the study.

Furthermore, I also affirm that the experimenter explained the study to me and told me about the study's risks as well as my right to refuse to participate and to withdraw.

Signature of Participant ______________________________ Date ____________

Printed name of Participant ____

APPENDIX B: ASSESSMENT DOCUMENTS

Mathematics Anxiety Survey

Name:________________

Your name will only be used to match your surveys.

Rate the following statements from 1 (strongly disagree) to 5 (strongly agree).

_____ Solving math "word problems" does not make me nervous.

_____ I am confident in my ability to use algebra.

_____ I can use math for everyday needs without feeling confused.

_____ I feel that my mathematics performance on tests represents my ability.

_____ When I think of completing an assignment for science class, I feel comfortable with the level of challenge and my mathematical ability to complete the assignment.

College Algebra Pretest

This assessment will be used for research purposes only and will not affect your grade. Please give your best effort in the time provided.

1. $2(5 * 3) - 7 =$ ________

2. $(4^2 - 2)3 =$ ________

3. $\frac{3}{4} + \frac{5}{6} =$________

4. $\frac{1}{2} * \frac{3}{5} =$ ________

5. $\frac{1}{2} \div \frac{3}{4} =$ ________

Combine like terms

6. $5x + 7 - 2x =$ ________

7. $4y + 3x - y + z + 2x =$ ________

Evaluate the expression

8. $3x + 5y - z \; for \; x = 2, y = -1, z = 5$

____

Physical Science Pretest

This assessment will be used for research purposes only and will not affect your grade.

Please print neatly and give your best effort in the time provided.

1. What is mass?

2. What is volume?

3. What is density?

4. What is energy?

5. What is a force?

6. What is the metric base unit of length?

7. What are the three particles that compose an atom?

8. If the north ends of two magnets are brought near each other, what will happen?

9. What is the charge of an electron?

10. What will happen if two negative charges are brought near each other?

Booklet Usage Survey

This survey is being used to determine if and how you have used the booklet provided. It is also a place for you to provide feedback to the researcher.

1. Did you use the booklet? (Yes/No) When? *If you chose no, skip to question 5.*

2. What did you primarily use the booklet for?

3. In what ways did the booklet affect your understanding of the physical science content?

4. How did the booklet affected your understanding of the mathematics related to physical science?

5. Which sections were particularly helpful?

6. If a new booklet were to be made, what would you want to be changed? *You may also add any other feedback you wish to provide.*

APPENDIX C: BOOKLET

Supplemental Mathematics Booklet for Physical Science

James C. Roberson

This booklet is intended to aid in the understanding of the content in your physical science class. It includes mathematics content that will aid you in understanding the science content.

This space is provided to track your use of this booklet. Please tally your uses according to the provided categories. Mark the ‘quick reference’ category if you spend less than a minute consulting the booklet. If you refer to an example to help guide you toward finding a solution, mark the ‘example check’ category. If you use the booklet for an extended period of time for the purpose of increasing your understanding of the topic, mark the ‘In-depth Study’ category.

Quick Reference:

Example Check:

In-depth Study:

The International System of Units

Your physical science class will be making extensive use of SI measurement units. This system is much different from the English measurement system you are likely accustomed to. Rather than fractions and highly variable unit conversion amounts, (ex: 12 inches per foot) the SI uses a base ten system throughout.

The SI has base units for each type of measurement. Those which apply to your class are listed as follows:

Length is measured in meters (m)

Volume is measured in liters (L)

Mass is measured in grams (g)

Force is measured in newtons (N)

Time is measured in seconds (s)

Energy is measured in joules (J)

Power is measured in watts (W)

Standard prefixes are used to make units size-appropriate for multiple applications. These prefixes represent the multiplication of the base unit by a factor of ten. Some of these units are listed here:

kilo	(k)	1,000	
centi	(c)	0.01	or 1/100
milli	(m)	0.001	or 1/1000

If you have a measurement of 1 Km, this would be equal to 100 * (1/1,000) m. You could say that you have 0.1 or 1/10 of a meter.

Fractions, Decimals, and Percentages

Using fractions in mathematics can be problematic for many. As they are directly related to decimals and percentages, these will be discussed together in this section. The most important thing to remember about a fraction is that it is simply the representation of one number being divided by another, without completing the process. 3/4 is the same as 3÷4, but written in a more convenient form. You will see many fractions in formulas throughout the class, so getting comfortable with them will be beneficial to you.

Multiplying fractions is easily accomplished by treating the top and bottom separately.

$$\frac{3}{4} * \frac{3}{4} = \frac{3 * 3}{4 * 4} = \frac{9}{16}$$

Dividing by fractions can look a little more intimidating, but you can change the way they are expressed to make them easier to deal with.

$$\frac{1}{2} \div \frac{2}{3} = \frac{\frac{1}{2}}{\frac{2}{3}}$$

Instead of dividing one fraction by another, you can multiply the top number by the inverse of the bottom number.

$$\frac{\frac{1}{2}}{\frac{2}{3}} = \frac{1}{2} * \frac{3}{2} = \frac{1 * 3}{2 * 2} = \frac{3}{4}$$

A decimal number is similar to a fraction. The number position of a decimal represents a factor of ten by which the number is divided.

$$0.1 = \frac{1}{10}$$

$$0.01 = \frac{1}{100}$$

$$0.003 = \frac{3}{1000}$$

A percentage is a number representing a fraction of 100.

$$5\% = \frac{5}{100} = 0.05$$

$$15\% = \frac{15}{100} = 0.15$$

Increasing an amount by 10% is easy to do when you know the relationship between percentages and decimals.*1 is used so that the initial amount is included.*

$$17.76 * 1.10 \approx 19.54$$

Equations

An equation is a way of expressing ideas with numbers and symbols that sets two or more components equal to each other. This relationship is represented with an equal sign '='. In physical science, relationships are often expressed through the use of equations.

Newton's second law can be written as F=ma. This means that the amount for force (F) is equal to the amount of mass (m) multiplied by the acceleration (a). This way of writing the formula is most useful when the variable you are solving for is (F). If you need to solve for the other two variables, the formula can be written in a way that makes this more convenient.

$$\frac{F}{a} = \frac{ma}{a} \to \frac{F}{a} = m \textbf{ or } m = \frac{F}{a}$$

$$\frac{F}{m} = \frac{ma}{m} \to \frac{F}{m} = a \textbf{ or } a = F/m$$

Velocity is a speed in a direction. Speed is expressed as a distance covered in a given amount of time. If an object has moved 10m in 5s, you can express its speed in m/s by using these two values. You can also determine how you need to arrange them by the units they are measured in.

$$speed = \frac{distance}{time}$$

$$speed = \frac{10m}{5s} = 2\frac{m}{s}$$

Rearranging the formula will allow you to solve for the other variables as well. If you are given a speed of 10m/s, how long will it take to move a distance of 300m? In this instance, you are solving for time.

$$(time)speed = \left(\frac{distance}{time}\right)time$$

$$\frac{(time)speed}{speed} = \frac{distance}{speed}$$

$$time = \frac{distance}{speed}$$

$$time = \frac{300m}{10\left(\frac{m}{s}\right)} = \frac{300}{10\left(\frac{1}{s}\right)} = \frac{300s}{10} = 30s$$

The last arrangement is solving for distance. How far will an object move in 20s with a speed of 7m/s?

$$speed = \frac{distance}{time}$$

$$distance = speed(time)$$

$$distance = 7\left(\frac{m}{s}\right) * 20s = 140m$$

Conversions

Converting between different types of units is another useful skill for your physical science class and life in general. Even when using the SI, information is not always provided to you in the form you need it to be in. Therefore, you will need to know how to change this information into the form you need.

Converting information requires a **conversion factor**. This is what relates the form of the information you are provided with to the form you need. A simple set of conversion factor you are familiar with are those for time. You know how many seconds are in a minute and can intuitively convert between the two. Your conversion factor is 60s per minute. As an exercise, determine how many seconds are in one week.

<u>conversion factors</u>

1 minute = 60 seconds

1 hour = 60 minutes

1 day = 24 hours

1 week = 7 days

$$1\ week * \frac{7days}{week} = 7\ days$$

$$7days * \frac{24\ hours}{day} = 168\ hours$$

$$168\ hours * \frac{60\ minutes}{hour} = 10{,}080\ minutes$$

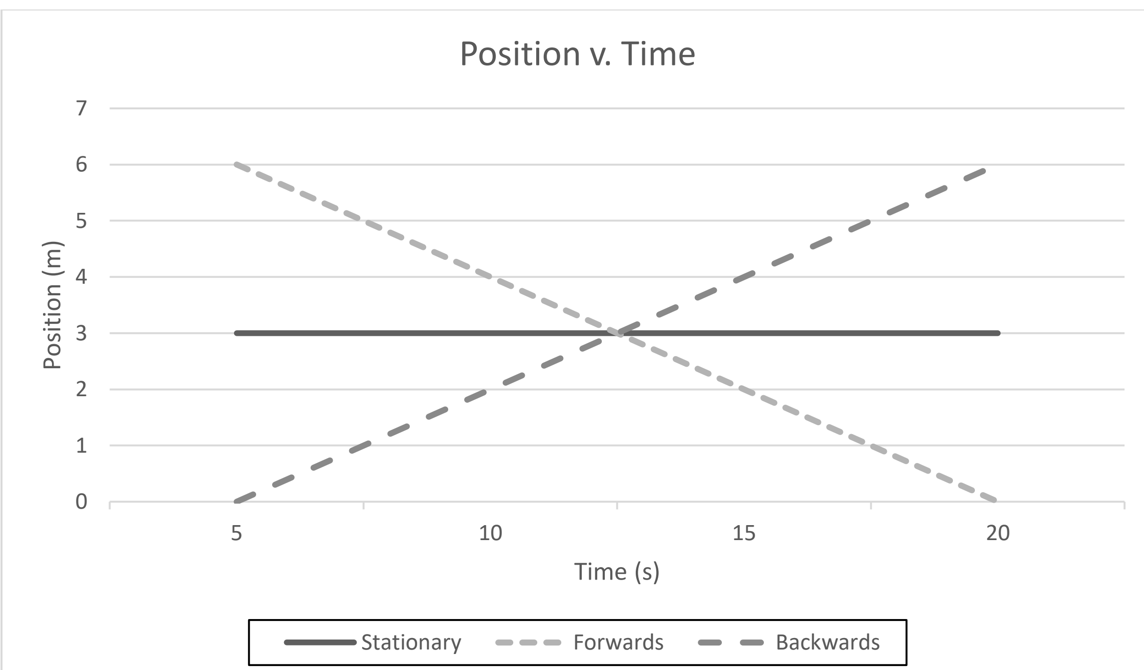
$$10{,}080\ minutes * \frac{60\ seconds}{minute} = 604{,}800\ seconds$$

This process can also be performed on a single line, if you prefer. What is the volume of a Kg of gold? Gold is 19.3g/mL.

$$1Kg * \frac{1{,}000g}{Kg} * \frac{1mL}{19.3g} * \frac{1L}{1{,}000\ mL} = \left(\frac{1}{19.3}\right)L \ \approx 0.05\ L$$

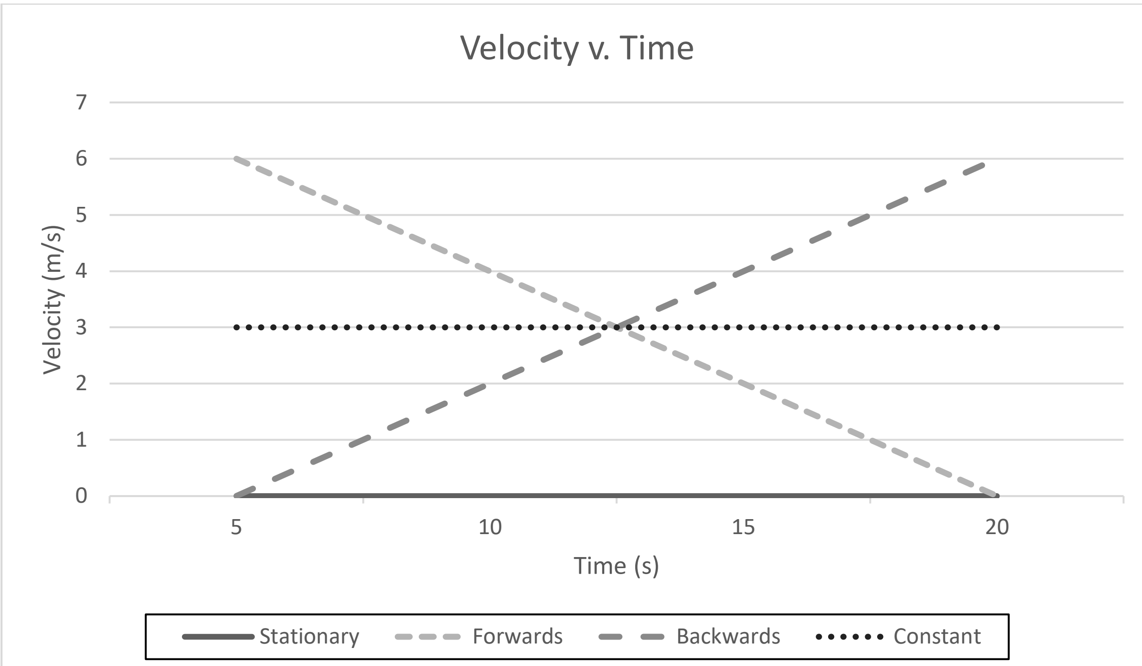
Graphs

Some information can be made less confusing by exploring the concept with graphs. The concepts of position, velocity, and acceleration will be explored here. Before the graph has meaning, you must establish what the directions indicate. For the following graphs, positive distances will be considered movement forward. Negative distances will be movement backwards. Zero meters will be the starting point.

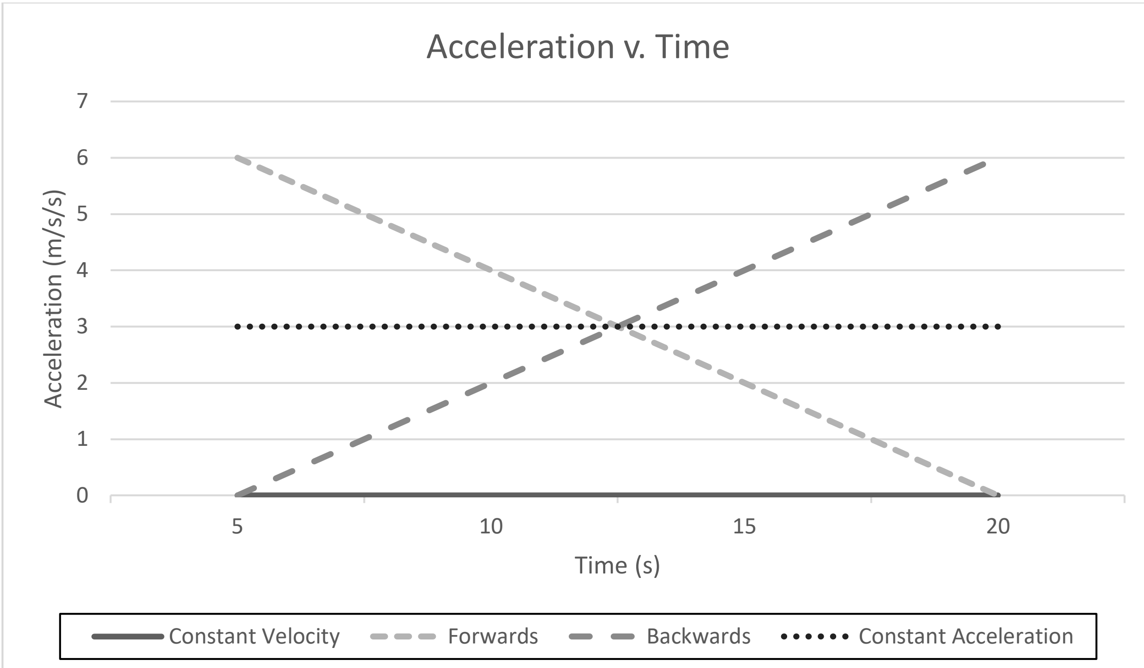


As you can see, a positive value (moving away) makes a line that slopes upward over time (left to right). A negative value (moving towards) makes a line that slopes downward over time. The line that stays horizontal represents no movement over the time graphed, at a position of three meters from the starting point. The slope of each line provides a velocity for that line.

You may also need to determine how velocity changes over time. A change in velocity over time is an acceleration. Movement away from the starting point will be considered positive in this example.



The line representing a stationary object remains on the zero line. This does not indicate the position of the object. It only indicates the object is not moving. The lines for towards and away look the same as in the graph of position over time, but represent the change in velocity relative to the starting point. Both of these lines represent movement away from the starting point because they are both positive velocities. The line ‘Towards’ shows a velocity beginning at 6 m/s and ending at 0 m/s. The line for ‘Away’ shows a velocity beginning at 0 m/s and increasing to 6 m/s. The new line on this graph is the ‘Constant’ line. An object with a constant velocity will produce a horizontal line on a graph. It is moving at a constant velocity of 3 m/s for this measurement.



In this graph of acceleration over time, zero acceleration is the constant velocity plot. The constant acceleration line is horizontal at 3 m/s. The ‘towards’ line indicates an increase in acceleration towards and the ‘away’ line indicates a decrease in acceleration away.

VITA

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Experience:

Adjunct Professor of Physical Science - Northwest Mississippi Community College: 2014-2017

Physical Science Lab Instructor - The University of Mississippi: 2010-2017