The Effect of an Integrated STEM Course on Middle School Students' Interest

and Career Aspirations in STEM Fields

By

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Abstract

The STEM Semantics Survey was employed to investigate the effect of a one semester integrated STEM lab course on middle school students' interest in STEM fields and STEM careers. A 2x2 repeated measures MANOVA was used to analyze the data. Significant results were not achieved when examining the data by treatment groups or by gender. Increases in science interest were observed in the overall sample, but the treatment group and comparison groups did not yield significantly different results. Previous research indicates that this type of course should cause changes in student interest which leads to new questions about the survey instrument, length of treatment intervention, and other factors that were not accounted for in the design of this study.

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CONTENTS

Table of Tables

Table of Figures

Chapter 1: Introduction

…leadership tomorrow depends on how we educate our students today—especially in science, technology, engineering, and math.—President Barack Obama (Sabochik, 2010)

The Global STEM Workforce

Discoveries in engineering, science, and technology fields drove huge advancements in the 20th century with similar trends expected in the coming decades (Ellis, 2008). In the first decade of the 21st century, employment opportunities in these fields grew at a rate three times faster than other fields (The United States Department of Commerce, 2012). These new jobs will continue to require employees with STEM and 21st century skills such as critical thinking, communication, and collaboration. Although a small percentage of these positions will require graduate level training and specialized education, a much larger percentage will require workers with mid-level skills and STEM competencies (Carnevale, Smith, & Melton, 2011).

In 2011, the National Research Council urged educators to increase the number of students pursuing STEM career pathways after high school with particular emphasis on traditionally underrepresented groups such as students of color, women, and students from low socioeconomic backgrounds. The challenge of creating a workforce of suffucient size and quality for a world that is increasingly dependent on technology requires inspiring all students to pursue and persist in STEM and to place particular emphasis on increasing participation of underrepresented ethnic groups and females (Miller, Ward, Sienkiewicz, & Antonucci, 2011).

Women in STEM

The number of women entering STEM Career fields has increased, but women are still a significantly underrepresented category of employees in STEM areas. In 1960, women represented 1% of employees in engineering fields. By the year 2000, that number had only increased to 11% (Jones, 2010). Recent reports confirm under-enrollment and under-representation of women and minority students in STEM fields. Statistics are equally grim at the graduate level with only 36% of STEM doctorates earned by women (Miller et al., 2011).

The American Association of University Women asserts that attracting and retaining more women in the STEM workforce will maximize innovation, creativity, and competitiveness (Hill, Corbett, St. Rose, & 2010). Further reports from the AAUW state the need for women in STEM careers to diversify thinking when accomplishing tasks such as finding cures for diseases and engineering buildings. A deficit of women in fields where products are engineered, designed, and created can cause women's needs to be overlooked. A diverse workforce is more likely to ensure that products and services are representative of all potential consumers.

Although slight increases in the number of women entering STEM careers have been reported over the past 50 years, the numbers of women who enter and remain in these careers are much lower than the number of men. Many reasons have been reported for this discrepancy including social, cultural, educational, and self-confidence factors (Hill et al., 2010). The aforementioned factors must be addressed while female students are young enough to make an impact on their future career choices. To increase the number of girls pursuing STEM fields, it is important to find successful strategies that encourage their interest and affirm their confidence in the areas of science and mathematics (Heaverlo, 2011). Heaverlo also maintains that it is essential for girls to learn STEM in a supportive environment that encourages a real life context for application of skills and information.

Only one quarter of the current United States STEM workforce is comprised of women. Two primary reasons for this figure are: women major in STEM fields in college at a lower rate than men, and women who do obtain STEM degrees often go on to work in other areas (White House Council on Women and Girls, 2012).

Student Career Choices

Studies show that after the implementation of No Child Left Behind, the amount of time devoted to science education at the elementary school level dropped significantly with results ranging from 178 minutes per week in some studies with others showing that 80% of K-5 teachers spent 60 minutes or less with 16% reporting no time spent on science (National Research Council, 2011). The decrease in time for science education is of significant concern because some research shows that interest in science careers may develop in the elementary school years. While there have been changes to the NCLB legislation, many school schedules still reflect the restrictions imposed under the original laws.

In an analysis of the *National Education Longitudinal Study of 1988* and the follow up studies from 1990, 1992, 1994, and 2000, researchers found that students who expected to have careers in physical sciences or engineering when surveyed during their eighth grade year were 3.4 times more likely to earn a bachelor's degree in those fields, and roughly half of the surveyed students followed through on their 8th grade career plans regarding entry into a science related career or another type of career field. Careful attention should be given to children's early exposure to science in order to attract students into science and engineering (Tai, Liu, Maltese, & Fan, 2006). Interest at 8th grade is not a guarantee of future STEM workers, but evidence suggests that developing the interest early is a step in the right direction.

K-12 and postsecondary students lack interest in STEM relative to societal and labor demands. More than three out of four students who score in the top quartile on mathematics assessments do not go on to major in STEM fields in college and of those who do major in STEM, only 50% complete their degree in a STEM area (Carnevale et al., 2011).

STEM Integration

An ever-changing, increasingly global society presents problems that are multi-disciplinary in nature. Many of these issues require STEM knowledge to find appropriate solutions (Roehrig, Moore, Wang, & Park, 2012). National calls for changes and increases in STEM education also result from the complex nature of these real-world problems (National Research Council, 2011; National Science Board, 2014). Professional societies such as the American Society for Engineering Education and the National Academy of Engineering also assert the necessity of new educational approaches that center around hands-on, interdisciplinary, and socially relevant aspects of STEM (Brophy, Klein, Portsmore, & Rogers, 2008). This is necessary to develop a new generation of STEM workers, but it is also vital to develop STEM literacy for all (Roehrig et al., 2012). Integration of STEM subjects offers students one of the best opportunities to experience learning in real world situations rather than learning piece by piece, but in the way STEM education is currently structured and implemented in most schools, it does not reflect "the interconnectedness of the four STEM components in the real world of research and technology development" (National Academy of Engineering, 2009).

Research in STEM integration within K-12 classrooms has not kept pace with the sweeping STEM policy changes and reports such as *Rising Above the Gathering Storm*, *Educate to Innovate*, and the *Next Generation Science Standards*; and research on effective models of STEM integration is lacking (Roehrig et al., 2012). Roehrig's research also indicates that full STEM integration may require new school organizational structures.

In an examination of eight journals related to STEM education, Brown (2012) reviewed 1100 articles published between 2007 and 2010 and found 60 that were specifically presenting results of STEM research in K-12 settings. Approximately half were presenting small research activities from a practitioner perspective while the other half presented academic research. The review indicates that there is a research base for STEM education, but academic studies analyzing integrated STEM instructional methods are "clearly missing." Brown's summary data suggests that further research is needed. Collaboration between research institutions and K-12 programs could yield academic research that will be essential in identifying ways to proceed in STEM education at the K-12 level. Practitioner journals have provided insight into the work of fellow teachers and activities for classroom teacher use, but a significant need for academic research is needed to demonstrate the effectiveness of STEM education initiatives in classrooms.

In a recent issue of *Educational Leadership*, an article geared toward school level practitioners interested in STEM education in K-12 schools shared several key points that are backed up in recent literature. STEM efforts in schools are often simply mathematics and science classes that are taught separately. When technology and engineering are occasionally integrated, the efforts are small scale and disjointed. However, several key ideas for success were shared. In order to implement high-quality pathways to advance STEM learning, there are four essential components: integrated curriculum, project-based learning, work-based learning, and continuous improvement (Hoachlander & Yanofsky, 2011).

Problem Statement

In a society where STEM careers are one of the fastest growing job sectors, and life is increasingly dependent on technology, maintaining excellence and competitiveness at the global level requires that increasing numbers of students emerge from P-12 school systems ready to pursue careers and higher education opportunities related to STEM fields. Science, mathematics, engineering, and technology are cultural achievements that reflect people's humanity, power the economy, and constitute fundamental aspects of our lives as citizens, workers, consumers, and parents (National Research Council, 2011).

In 2011, the National Research Council also presented three broad and widely espoused goals for K-12 STEM education in the United States. The three goals are not intended to be mutually exclusive, but they are intended to collectively capture the breadth of the purpose of STEM education and reflect the intellectual capital that is necessary for the nation's continued growth and development in an increasingly science- and technology-driven world. In summary, the goals are to increase advanced training and careers in STEM fields, to expand the STEM-capable workforce, and to increase scientific literacy among the general public. In order to reach these long-term goals, intermediate steps must be taken. Suggested intermediate goals include learning STEM content and practices, developing positive dispositions toward STEM, and preparing students to be lifelong learners. The three specific long-term goal statements are:

- Goal 1: Expand the number of students who ultimately pursue advanced degrees and careers in STEM fields and broaden participation of women and minorities in the fields.
- Goal 2: Expand the STEM-capable workforce and broaden the participation of women and minorities in that workforce.
- Goal 3: Increase STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines.

Current scientific research provides little evidence about how to accomplish the three broad goals.

In elementary school, a majority of students are interested in science, technology, engineering, and mathematics (STEM.) Students lose interest during middle school years. More girls than boys lose interest in STEM during the middle and high school years. While student interest in school and specifically STEM subjects tends to decrease during the middle school years, the problem is worse for girls than boys (Naizer, Hawthorne, & Henley, 2014). During elementary school, female students perform as well as or better than their male peers on most aspects of mathematics and science, but girls are much less likely to maintain their early affection for mathematics and science (Orenstein, 1994).

Reports show that although more women are entering STEM career fields, women are still significantly underrepresented in these fields. Approximately 1% of women were represented in engineering fields in 1960. In 2000, the percentage had increased, but the level was still only 11% (Jones, 2010).

Students begin making career decisions before entering high school those choices are often stable over time. Most students make decisions about their educational future between 8th and 10th grades (Gibbons & Borders, 2010). If students are making future educational and career decisions, it is essential for students to have appropriate educational experiences in middle school to allow them to make effective decisions. The probability of students persisting in STEM is greatest if they choose a STEM career or show significant interest in STEM by the eighth grade (Miller et al., 2011). By the time students reach 8th grade, twice as many boys are interested in quantitative disciplines and science careers than girls regardless of race and ethnicity (Campbell, Jolly, Hoey, & Perlman, 2002). Some studies show that students are beginning to retain more interest in STEM classes particularly at younger ages, but interest in related careers is still low. Reasons why interest remains low include perceived difficulty of future classes in high school or college, few role models, long work hours, misunderstanding of career options, and perceptions of isolation within STEM career fields.

Research Questions

1. What is the effect of a one semester STEM Lab course on middle school students' overall interest in STEM fields?
    a. What is the effect of a one semester STEM Lab course on middle school students' overall interest in science?
    b. What is the effect of a one semester STEM Lab course on middle school students' overall interest in technology?
    c. What is the effect of a one semester STEM Lab course on middle school students' overall interest in engineering?
    d. What is the effect of a one semester STEM Lab course on middle school students' overall interest in mathematics?

2. What is the effect of a one semester STEM Lab course on middle school students' interest in STEM careers?
    a. What is the effect of a one semester STEM Lab course on middle school students' interest in pursuing educational opportunities that could lead to a STEM career?
    b. What is the effect of a one semester STEM Lab course on middle school students' perception of supportive environment for pursuing a career in STEM?
    c. What is the effect of a one semester STEM Lab course on middle school students' perceived importance of a career in STEM?
3. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in STEM fields differ by gender?
    a. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in science differ by gender?
    b. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in technology differ by gender?
    c. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in engineering differ by gender?

d. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in mathematics differ by gender?

4. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in STEM careers differ by gender?
   a. Does the effect of a one semester integrated STEM Lab course on students' interest in pursuing educational opportunities that could lead to a STEM career differ by gender?
   b. Does the effect of a one semester integrated STEM Lab course on students' perception of a supportive environment for pursuing a career in STEM differ by gender?
   c. Does the effect of a one semester integrated STEM Lab course on students' perception of supportive environment for pursuing a career in STEM differ by gender?

Although anecdotal evidence supports the belief of many educators and researchers that integrated STEM education can positively affect students, P-12 STEM programs need to conduct research on the extent to which they are reaching all students. This research must focus not only on acquiring content and skills. It must also investigate students' interest and STEM identity—developing a sense of self as a learner and as a potential STEM professional. One of the underlying conjectures is that "engineering education enriches teaching and learning for all learners in P-12 environments and impacts outcomes across multiple areas of STEM content and processes" but further research is necessary to support these claims (Brophy et al., 2008). Brophy et al also maintain that programs need to conduct more *rigorous academic research* on P-12 engineering education programs' effect on *all* students. Brophy cautions that the research must determine if the programs are truly developing new and diverse interests and talent or simply "capturing the hearts and minds of students already interested in pursuing STEM."

Local Perspective

History of STEM Lab Course Development

In the 1990s, students at The Middle School participated in related arts courses that included general music, computer applications, home economics, wood shop, and art. In the 1990s, the shop and home economics courses were combined into one course called Tech Lab. Each year, students would participate in Tech Lab for one quarter of instruction and would participate in assigned modules to learn basic skills of cooking and home repair, along with adding a few engineering and STEM related topics such as programming and building rockets. The course was team taught by the former shop and home economics teachers.

With the Kansas State Department of Education's adoption of the Common Core State Standards for Mathematics as the Kansas College and Career Ready Standards for Mathematics and the Next Generation Science Standards as the Kansas College and Career Ready Standards for Science, the Tech Lab course has been refined and redesigned to incorporate a greater focus on STEM. Starting in the fall 2014, all 7th and 8th grade students at The Middle School take a redesigned semester-long course focusing on application of STEM skills. Through a variety of engineering modules and projects, students have the opportunity to further develop and apply skills that are taught in their science, mathematics, and computer courses. The STEM Lab program allows students to further investigate topics as an integrated whole rather than isolated subjects.

Course modules of study include chemical mathematics, engineering towers, flight technology, forces, forensic math, genetics, geometric packing, heat & energy, laser geometry, plants & pollination, population perspectives, sports statistics, 3D modeling, and statistical analysis. (See appendix for course module descriptions, objectives, and performance assessment activities.) During the course, students are guided in choosing modules that develop needed skills while focusing on areas of student interest. Students work with a partner or small team to complete modules while practicing 21st Century skills of teamwork, effective communication, inquiry, self-directed learning, and social skills. The teacher acts as a facilitator to guide students and provide feedback. Short introductory direct instruction is given at the beginning of the semester to introduce procedures, overall topics, methods, and general goals for the course, but the majority of the course is student driven and inquiry and engineering oriented.

In 2013 a group of 39 acknowledged experts were asked to collaboratively develop a list of technologies that will significantly impact education through the year 2018. One technology that was predicted to make a significant impact in STEM education in the year 2015 or beyond is 3D printing and modeling (Schaffhauser, 2013). This technology is currently used in a significant educational experience during the STEM lab course at The Middle School. During this semester-long course, students spend approximately 3-4 weeks working with 3D modeling and have access to 3D printers to bring real world application to an otherwise abstract process.

District Description and Demographics

The selected school district is located in a small community located approximately 25 miles outside of the Kansas City metro area. The town had approximately 5,600 residents as of the 2010 Census, and the school district also serves a significant portion of the surrounding rural area. The district serves nearly 2,000 students in grades K-12.

School	Grades	Enrollment 2013-2014
******** Elementary	K-2	447
******** Elementary	3-5	444
******** Middle School	6-8	453
******** High School	9-12	611

The selected school district is designated as a Title 1 district, and has approximately 38% economically disadvantaged students. The district population is 90% Caucasian, 4% Hispanic, 2% African American, and 4% other ethnicities. The Middle School closely resembles the district socio-economic and ethnic compositions. The district has less than 1% English Language Learners and a 14% rate of students with disabilities.

Current Course Content Options

All students are enrolled in four core academic subjects: mathematics, science, social studies, and communications which is an integrated English Language Arts course. All students participate in a daily physical education course during all three years of middle school. A daily seminar course is offered for all students unless they are enrolled in band or journalism which meet during the seminar block. During the seminar time, students may work on assignments or projects, seek additional help or enrichment from a teacher, or read. Each core content teacher is responsible for one seminar section each day.

Subject	**Grade**	**Courses and/or Core Content**
Mathematics	6th	General Mathematics 6
	7th	General Mathematics 7 Pre-Algebra
	8th	Pre-Algebra Algebra
Science	6th	Earth Science
	7th	Life Science
	8th	Physical Science
Social Studies	6th	World History
	7th	Geography & Kansas History
	8th	US History
Communications	6th	Communications 6
	7th	Communication 7
	8th	Communications 8

Related Arts Courses

Grade Level	Course Length	Course Offerings	Requirements
6th	1 quarter (9 weeks)	General Music Art Computer Applications Tech Lab	All students must take a one quarter introductory version of each course
7th/8th	1 semester (18 weeks)	Choir Art Computer Applications STEM Lab	All students must take computer applications and STEM lab for one semester each at some point during 7th or 8th grade. Students may choose to take art and/or choir for their other two related arts semesters.

In each core academic class, the student to teacher ratio is approximately 27:1. At the sixth grade level, students are divided into three pods with two core content teachers per pod. Each teacher is responsible for teaching two core content subjects (i.e. communications and history or science and mathematics.) For 7th and 8th grade, there are 6 sections of each core subject. With the exception of mathematics where students are assigned to leveled mathematics courses based upon MAP (Measures of Academic Progress from NWEA) scores and teacher recommendation, all core class assignments are made through random selection using the Infinite Campus student data management system.

Summary

The continually increasing need for STEM workers is an issue of significant concern in the United States. In order to create supply to meet the demand, K-12 institutions in the US need to examine current programs in order to increase achievement and interest in STEM subjects and careers. There is a particular need for eliminating the gender gap in STEM fields. While the achievement gap has narrowed or closed, the number of female students pursuing, or interested in pursuing, advanced STEM education or STEM careers is much lower than the number of interested male students. Integrated STEM courses and programs are suggested in the research as a viable option to increase student interest in STEM subjects and STEM careers with particular emphasis on the opportunity to close the gender gap. The STEM Lab course at The Middle School provides a unique integrated STEM learning opportunity for all students. With the current course structure, it is possible to investigate the effects of this program on an entire population of students rather than focusing solely on students who self-select STEM education opportunities. Investigating the effect of this course on student interest in STEM subjects and STEM careers may provide enlightening evidence for future STEM programs across the country.

Chapter 2: Review of Literature

Historical Perspective

The STEM movement has been brought to the forefront with a sense of urgency in recent years, but since 1944 the United States has commissioned reports with similar purposes—to identify potential solutions to improve the lack of STEM talent in this country. The first report, *Science, the Endless Frontier*, was a response to perceived competition from Germany and Japan (Zollman, 2012). On October 4, 1957, the Soviet Union launched the Sputnik satellite. This event was an impetus that lead to the formation of NASA in July 1958 when Congress passed the National Aeronautics and Space Act and sparked interest in STEM subjects in the United States. Also in 1958, Congress passed the National Defense Act which provided 1 billion dollars in loans, scholarships and fellowships for students in STEM fields, and created the National Science Foundation. Although it took over a decade, America was able to respond to the challenge and place the first humans on the moon. Throughout this time, significant attention was placed on preparing a workforce capable of supporting the visions and goals set forth to ensure global competitiveness and national security.

Through the years, hundreds of reports similar to *Science, the Endless Frontier* have followed. These reports have three unifying themes: goals for increasing the supply pipeline of scientists, engineers, mathematicians, and technicians; necessity to develop a knowledgeable population; and recommendations for how schools should be involved in the process. Addressing these three issues is necessary to meet societal needs for new advances, to resolve economic and national security concerns, and to fulfill individuals' personal needs to be productive and knowledgeable citizens (Zollman, 2012).

In the early 1980s, *A Nation at Risk* was published and in response, the American Association for the Advancement of Science (AAAS) created Project 2061 and subsequently published *Science for All Americans* in 1989 with the intent to encourage scientific literacy. Throughout the 1990s, reports and other documents from national commissions and professional organizations such as the National Science Teachers Association and the National Council of Teachers of Mathematics, along with researchers, employers, university faculty, and students called for innovations in science, mathematics, engineering, and technology education (Breiner, Harkness, Johnson, & Koehler, 2012).

What is STEM?

Although the roots of the STEM movement date back to President Dwight D. Eisenhower, and the formation of NASA and NSF, the original acronym used for the modern STEM movement was SMET. However, there were concerns about using the term SMET due to vulgarity. The current acronym STEM was introduced at NSF in 2001 by Dr. Judith Ramaley, assistant director of the Education and Human Resources Directorate. When she introduced the term, she explained that STEM is an educational inquiry process where learning would be placed in context, students would solve real-world problems, and opportunities would be created. It would be the pursuit of innovation (Daugherty, 2013). STEM has become one of the largest reform efforts over the past decade, and the acronym is widely used although there is some concern that many interested groups and individuals in politics, corporations, and the media may not fully understand the term in its true educational context. Often the term is used to refer to any study of one of the subjects within STEM rather than the true integration of the subjects as the original term intended (Breiner et al., 2012; Daugherty, 2013; Zollman, 2012).

STEM integration is an effort to combine the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based upon connections among these disciplines and real-world problems. Moore and Smith (2014) assert more specifically that STEM integration refers to students participating in the engineering design process in order to develop relevant technologies that require meaningful learning through integration and application of mathematics and/or science. The roots of STEM integration are based in the progressive education movement of the early 1900s and more recently in the socio-cognitive research movement

Current Influences on STEM Education

Much of the push to incorporate engineering into P-12 education has developed from concern about the quality, quantity, and diversity of the future engineering talent pool. The rapid evolution of technology necessitates that students must be educated differently in the P-12 system if they are to be successful in higher education institutions that are working to provide a diverse

STEM talent pool. Currently these institutions are seeing declining enrollment and less diversity among candidates (Brophy et al., 2008).

In 2007, *Rising Above the Gathering Storm* (Committee on Prospering in the Global Economy of the 21st Century) presented STEM as a call to action in response to low student performance in science and mathematics. The recommendations include: increasing the talent pool by improving K-12 science and mathematics education; sustaining and increasing long-term research; developing methods to attract and retain the best and brightest scientists and engineers; and increasing initiatives for innovation. Since the release of this report, organizations such as NSTA and legislators at state and national levels have promoted STEM skills by as the keys for future careers, success in higher education, national security, and global competitiveness (Breiner et al., 2012).

Current standards documents for mathematics, science, and technology all recommend and encourage connections between the subject areas to improve student attitude and achievement in the STEM subjects (Berlin & White, 2012). The Common Core State Standards for Mathematics recommend a significant level of integration with other subject areas as well as learning mathematics concepts in a practical, real-world context. Next Generation Science Standards also recommend that science be integrated with mathematics, technology, and engineering concepts.

Integrated STEM Education

Benefits

Research indicates that using an interdisciplinary or integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners (Stohlmann, Moore, & Roehrig, 2012). Other benefits include student centeredness, improved higher level thinking skills and problem solving, and increased levels of knowledge and skill retention. Research into integrated STEM education also reveals similar benefits. Morrison (2006) indicates that STEM integration creates students who are problem solvers, innovators, inventors, self-reliant, logical thinkers, and technologically literate. The National Academy of Engineering and the National Research council indicate that integrating engineering into K-12 curriculum can lead to improved achievement in mathematics and science, increased awareness of engineering, understanding and being able to do engineering design, and increased technological literacy. Other studies show links to positive impact on student attitude and interest in school, improved motivation to learn, and increased achievement (Stohlmann et al., 2012). The NAE report explicitly states “there is considerable potential value, related to student motivation and achievement, increasing the presence of technology, and especially, engineering in STEM education in the United States in ways that address the current lack of integration in STEM teaching and learning” (p. 150). The report continues on to indicate that engineering provides a vehicle and methodology for learning science and mathematics because “in the real world, engineering is not performed in isolation—it inevitably involves science, technology, and mathematics. The question is why should these subjects be isolated in schools” (p. 164-165).

Learning science and mathematics through an integrated engineering design process enhances knowledge and critical thinking skills and promotes interest in science and engineering careers (Lehman, WooRi, & Harris, 2014). Engineering activities and goals are not trivial and can be intrinsically motivating as they tap a natural desire to make things and learn how things work. Therefore it logically follows that learning through engineering design is a popular model used in science, mathematics, and technology education (Brophy et al., 2008).

Methods

Integrated STEM education allows teachers and learners to focus on big ideas that connect subjects. For authentic learning to take place, students must have opportunities to design processes and products. Integrated STEM education often incorporates a wealth of resources and materials to allow students to investigate real world problems through designing, expressing, testing, and revising their ideas (Stohlmann et al., 2012). The placement of engineering standards into the *Next Generation Science Standards* is an unmistakable policy statement that STEM integration is the desired outcome (Roehrig et al., 2012). True STEM education should increase students' understanding of the interconnectedness of science and mathematics in order to advance engineering and technology. This integrated approach to STEM education naturally necessitates authentic learning experiences (Hernandez et al., 2014). Engineering design projects can serve as a catalyst for integrating learning across STEM disciplines ((National Academy of Engineering, 2009).

Hernandez et al. (2014) illuminates the striking similarities between the engineering and technology core concepts and practices integrated within the new science standards and the findings from cognitive science that define good instruction.

1. Students learn to engage actively with the learning process and content
2. Through instructional design, students learn to reflect on and connect existing structures of knowledge to guide and further their learning
3. Students learn to interact in classrooms or communities of learning where knowledge and information are shared openly in an environment that values participation and interaction between students, teachers, and sources of knowledge outside the classroom

The application of the above principles results in classrooms that engender design experiments, collaborative learning experiences, socially-distributed expertise across teams of students, and project based learning. Therefore, classrooms embodying these principles will display multi-disciplinary student design teams, shared expert knowledge, student-led design and engineering tasks, and authentic scientific and engineering practice.

In engineering design contexts, learners have the opportunity to evaluate complex systems such as elbows or lungs. This requires them to notice features of structure, function, and behavior. Hands-on learning during "making" activities provides experience with properties of materials and physics principles. Regardless of the specific task, design activities require learners to notice and reflect on processes, devices, or natural phenomena to ask the initial questions such as, "What should I make?," "How does it work?," "What factors in the design are critical to my goals?," or "What can I manipulate to achieve my goals?" (Brophy et al., 2008). Brophy et al continue to state that engineering design principles are inquiry-based models of instruction grounded in constructivist theories of learning and are guided by similar principles that consider "the learner, the knowledge to be learned, assessment practices, and community in the classroom and in the profession."

Effectiveness

A significant portion of the most recent discoveries and most valuable knowledge in STEM fields involve more than one subject area. Advances in science are rarely possible without involvement of technology, engineering, or mathematics. Integrated STEM education leads to increased interest in STEM field careers and may improve student performance in mathematics and science. Effective STEM education is essential for student success as they progress into the future (Stohlmann et al., 2012). The engineering design process is one project-based approach that can be used to promote science learning. Teaching through engineering design has the potential to facilitate integrated instruction necessary to meet the new standards' expectations of integration, inquiry, and cooperative learning. These processes allow students to collaborate, come to new understandings, and relate new understandings to other concepts and prior knowledge (Lehman et al., 2014).

Women in STEM

In a letter to the President, members of the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development (CAWMSET) sum up a significant problem. "If majority women and minority women and men were getting degrees in the quantitative disciplines, including math, economics, engineering, and computer and physical sciences at the same rate as their representation in the general population, there would be more than a million more workers in those fields." All of those additional workers and their varied experiences and viewpoints would be needed (Campbell et al., 2002).

Interest in science and mathematics often peaks during the middle school years for young women and minorities. New studies indicate that although young women are as academically competent in STEM disciplines, they often feel that STEM is not relevant to their future career goals or find the learning context uninviting (Brophy et al., 2008).

Effective STEM Education

The Dayton Regional STEM Center (DRSC) and the University of Dayton (UD) formed a partnership under an NSF grant. The project goal was to develop effective STEM educational opportunities. In order to bring stakeholders together and examine the current status of STEM education, the two partner organizations developed the STEM ed Quality Framework (SQF) to articulate their shared vision for STEM education (Pinnell et al., 2013). The framework incorporates ten components with quality standards to accompany each component. In full versions of the framework, rubrics are available to assess the components at a deeper level. The framework is included in the figure below.

Figure 1 STEM Education Quality Components

STEM Education Quality Components

#	Components	Descriptions
1	Potential for Student Engagement	*Quality STEM learning experiences hold high potential for engaging students of diverse academic backgrounds.*
2	Degree of STEM Integration	*Quality STEM learning experiences are carefully designed to help students integrate knowledge and skills from Science, Technology, Engineering and Mathematics.*
3	Connection to the Broader Curriculum	*Quality STEM learning experiences help students connect STEM knowledge and skills across the curriculum.*
4	Nature of the Problem, Project or Task	*Quality STEM learning experiences challenge students to develop their problem-solving and project management skills.*
5	Quality of the Cognitive Task	*Quality STEM learning experiences challenge students to employ higher order thinking skills.*
6	Connection to STEM Industries	*Quality STEM learning experiences place students in learning environments that replicate work in STEM industries providing opportunities for STEM career exploration.*
7	Degree of Collaboration	*Quality STEM learning experiences often require students to work and learn in teams.*
8	Authenticity of Assessments	*Quality STEM learning experiences require students to demonstrate knowledge and skill through authentic tasks.*
9	Application of Engineering Design	*Quality STEM learning experiences require students to demonstrate knowledge and skills fundamental to the engineering design process.*
10	Quality of Technology Integration	Quality STEM learning experience requires students to employ multiple technology tools and resources in ways that mirror their use in the STEM fields.

Career and Higher Education Choices

Offering an experience that ensures students are aware of future options is one method to influence whether students seek degrees in STEM fields. Although prediction models currently indicate that academic performance in eighth grade is a significant predictor variable, the effect of family and teachers that encourage the student to consider or pursue STEM indicates that early intervention is essential as well (Nicholls, Wolfe, Besterfield-Sacre, & Shuman, 2010). Nicholls et al have three recommendations for future implementation. First, improve educational preparation before and through junior high school. Second, engage the interest of students in scientific and quantitative fields in order to maintain STEM as a career option. Third, improve college level programs to support and interest students in STEM fields of study.

Middle school children are in formative years when they are making decisions that will affect their future educational and career opportunities. Students who do not envision themselves in STEM careers or do not like STEM related subjects begin to make pathway choices that may be difficult to change in the future. Curriculum, instruction methods, and other academic experiences can significantly impact those decisions, so not cultivating qualities of engineering, problem solving, and inquiry can be a great disservice to students and to the nation. Engineering education can broaden the pipeline of talent and prepare students to take the lead in developing an adaptive society for a rapidly changing world (Brophy et al., 2008).

Rising Above the Gathering Storm (Committee on Prospering in the Global Economy of the 21st Century, 2007) lists enlarging the pipeline as a major action to improve K-12 education and meet future needs of the nation. In order to increase the number of students prepared to enter college and graduate with a degree in science, engineering, or mathematics, K-12 systems must improve mathematics and science education. The next generation of scientists and engineers will only be able to transform the future if efforts to prepare students begin in early middle school. All students should have access to rigorous coursework and be held to high standards.

Interest in STEM

Three aspects are key to student advancement in STEM and quantitative disciplines: achievement, course-taking and interest (Farenga & Joyce, 1999). While some research shows that the gender gap in achievement has narrowed or closed, other research continues to report gender differences in affective dispositions such as interest (White House Council on Women and Girls, 2012). The small percentages of female students pursuing degrees and careers in physics, engineering, and similar fields clearly indicate a disconnect between girls' scientific achievement and their desire to pursue STEM careers. In K-12 education, girls often do not identify with STEM subjects regardless of test scores. Decades have been spent pursuing the achievement gap, but very little time has been spent addressing the identity gap (Tan, Calabrese Barton, Kang, & O'Neill, 2013).

Interest is an essential component in the development of personal identity and advancement in STEM education. Zollman (2012) presents identity development as the affective domain component of STEM education. Students initiate identity work as they begin considering personal competencies and attributes, setting goals, and evaluating personal beliefs. STEM identity is defined according to three key areas: interest in STEM and STEM careers, self-concept as it relates to STEM domains, and the influence of role models on student perceptions of STEM professionals (Hughes, Nzekwe, & Molyneaux, 2013).

Gilmartin et al (2007) defined positive science identity as a “combination of students’ self-perceptions and interest in science and science related work.” Eccles (2007) has found that intrinsic interest has a major impact on individuals’ persistence in STEM careers.

Student interest in STEM appears to decline with age. By eighth grade, regardless of racial/ethnic group, twice as many boys as girls are interested in quantitative disciplines and science careers (Campbell et al., 2002). Researchers, educators, and policy makers all assert that keeping girls interested in STEM during middle school is important for improving their overall persistence in STEM at the college and career level (Hill et al., 2010).

How Girls Learn

Sadker & Sadker (1994) express concerns regarding the general state of education for female students in the United States, and they iterate a need to address gender issues in the current curricula and systems. Many female students express learning preferences that are at odds with more traditional teaching methods that are used in science, mathematics, and computer classes at the middle school level and beyond. One idea often expressed is the desire for interaction, teamwork, and real world application of the material learned. In a comprehensive review of literature on girls and science education, Brotman and Moore (2008) note that multiple studies provide evidence that girls are, on average, more relational and less competitive than boys. Their evidence also suggests that girls strive for deep conceptual understandings and reject more formulaic, rote learning. In other studies they examined, hands-on and inquiry based learning had an effect on girls' achievement that was at least equal to and often greater than boys' achievement. Studies on topics of interest yielded information that both boys and girls prefer science instruction to be based in practical and societal applications rather than learning science for its own sake. This preference was stronger for girls and occurred in a greater majority of students.

In mathematics, girls actually outperform boys on structured tasks that involve applying procedures taught within a class, but when girls are presented with applied problems that require extension beyond what is taught in a class, girls begin to fall behind (Hyde, Fennema, & Lamon, 1990; Mendes-Barnett & Ercikan, 2006). The performance gap is attributed to girls' deference to authority and hesitance to branch out from the methods learned in class. In order to counter this, girls need to be given the freedom to think creatively and participate in mindful learning. When these techniques are applied, performance of female students is on par with male students (Anglin, Pirson, & Langer, 2008). When working with 6th graders in Massachusetts, researchers found that using mindful learning equalized performance for male and female students. Researchers presented material *conditionally* and showed a solution method as *one possible way* to solve the problem rather than *absolutely* where the method presented was *the way* to solve the problem.

Influence of Middle School and Early High School Coursework on Future Opportunity

The belief that one is good at a subject is one significant indicator in whether a student will continue pursuit of that subject at higher levels in high school and beyond. It is imperative that middle school students develop self-efficacy in STEM subjects in order to maintain options for higher education. Many students make course choices in early high school that significantly limit their options when approaching higher education. As students transition from middle school to high school, many students are making course choices that will hinder their options to pursue STEM education in college. Course choices can impact exam scores, entrance eligibility, and scholarship availability when entering institutions of higher education.

Theoretical Framework

This study is grounded in two theoretical frameworks. The instructional design of the integrated STEM Lab course used as the intervention in this study is grounded in Bruner's theory of Discovery Learning. The intervention is expected to positively affect student attitudes toward STEM and increase interest in future STEM careers within the Social Cognitive Career Theory (SCCT) proposed by Lent as a result of Bandura's (1986) social cognitive theory of learning.

Bruner's theory of Discovery Learning falls underneath the broad umbrella of Constructivism. Bruner's work began in the 1950s and spanned more than four decades. Bruner's theory asserts that instruction must be centered on experiences within contexts that make the student willing and able to learn. The instruction must also be structured in a way that students can grasp the concepts in a reasonable manner. Finally the instruction should be designed to facilitate opportunities for students to go beyond the minimum expectations and fill in gaps in their knowledge. Discovery Learning encourages problem solving situations in which students are required to draw on past experiences and existing knowledge to uncover new information and create new connections and relationships between ideas. Bruner's theory emphasizes that retention of knowledge is more likely when students are engaged in real-world and contextualized problem-solving rather than traditional transmission methods (Bruner, 1960, 1963, 1995).

Integrated STEM instruction is a modern product of the general curriculum integration movement that developed from the constructivist movement. Although integration is often referred to as a novel concept compared to the current status of curricula in schools, it is not a new idea. Bruner's work in the 1950s and beyond as well as many other constructivist theorists such as Dewey, Piaget, and Vygotsky indicate that real world contexts and cross-curricular problems are essential for effective learning. In 1974 Hirst pointed out that artificial separation of subject areas restricts learning because it removes students from the real-world experience (Roehrig et al., 2012). Numerous researchers and educators accept that integration of curriculum provides meaningful learning experiences for students by connecting content knowledge with personal and real-world experience (J. Beane, 1991; J. A. Beane, 1995; Burrows, Ginn, Love, & Williams, 1989; Capraro & Han, 2014; Childress, 1996; Jacobs, 1989; Sweller, 1989).

An essential component of Lent's Social Cognitive Career Theory (SCCT) is the importance of self-efficacy in developing career interests and forming academic goals (Lent, Brown, & Hackett, 1994, 2000; Lent, Lopez Jr, Lopez, & Sheu, 2008). Bandura's social cognitive theory of learning indicates that the most important component to goal setting and action is self-efficacy, an individual's belief that she is capable of mastering events within her own life. Social cognitive theory also suggests that outcome expectations affect interest when interacting with self-efficacy. The SCCT connects Bandura's relationship between self-efficacy, outcome expectations, and goals to contextual factors, personal inputs, and interests in order to explain how individuals make career related decisions. (See figure below) Career choices are often modified by performance outcomes that follow the decision. Revising perceived capabilities can ultimately prompt a change in goals. Therefore attitudes, including interest and self-efficacy, are essential in prompting students to pursue or continue to pursue particular careers. Another component of the SCCT that is of particular relevance to this study is the inclusion of gender as not only a biological construct but also a person factor of profound social significance. Race and gender are relevant to career development much more from their connection to the social/cultural environment than from their presence as biological attributes. The term gender has been chosen for this study rather than the term sex due to the constructs proposed in the SCCT. Gender role socialization and numerous other factors may bias boys' and girls' access to information needed to develop strong efficacy in particular activities.

Figure 2 Social Cognitive Career Theory

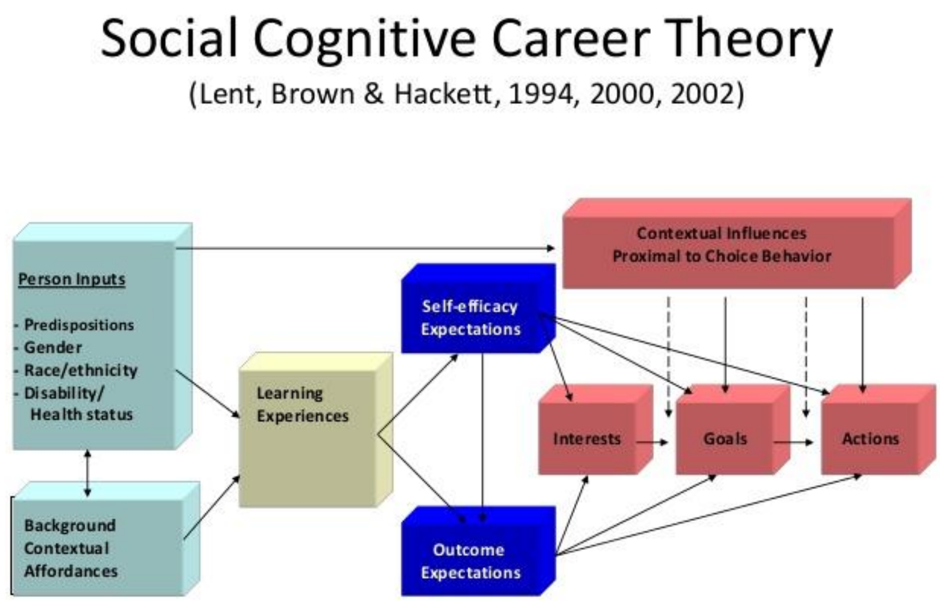


Figure 3: Social Cognitive Career Theory

Chapter 3: Methodology

Introduction

The purpose of this study was to determine if students who complete the integrated STEM Lab course at The Middle School have higher levels of interest in STEM fields of science, mathematics, engineering, and technology than their same age peers who have not completed the course. Both an overall interest in STEM and interest in the individual fields of science, technology, engineering, and mathematics will be examined. This study was also designed to determine if students who have completed the course have higher levels of interest in pursuing STEM careers and perceptions related to STEM careers.

This study also examined the effect of gender on the interest in STEM fields and careers. According to current literature and historical evidence, female students are significantly less likely to pursue STEM careers. While there are a variety of reasons for this suggested in the literature, this study simply focused on the difference between the results for male and female students rather than on the reasons for the differences. If the results of this study had shown that there is a difference in the results for male and female students, further follow-up study would have been warranted to examine potential reasons for the differences in results in order to provide effective and appropriate instructional opportunities for students of both genders.

Study Design

This study used repeated measures 2x2 factorial MANOVA design. The STEM Semantics Survey and the STEM Career Interest Questionnaire, developed at University of Texas as part of the ITEST initiative, were used as the measurement instruments. The instruments were administered as a pretest at the beginning of the fall 2015 semester and as a posttest at the end of the fall 2015 semester. Students enrolled in the STEM Lab course served as the treatment group and students who have not taken the STEM Lab course and were not currently enrolled in the course served as the comparison group. MANOVA is believed to be the most appropriate type of analysis since the literature indicates that the variables chosen were highly correlated.

Due to the inclusion of gender and course completion as the two independent variables and multiple dependent variables, a two way repeated measures mixed MANOVA analyses was run on the data. The design of the first analysis was a 2x2 factorial with two levels of gender and two levels of treatment. The dependent measures were overall interest in STEM fields, interest in science, interest in mathematics, interest in technology, and interest in engineering as measured by the STEM Semantics Survey.

A second analysis repeated the procedures using two levels of gender and two levels of course completion as the independent variables, but the dependent variables are based off the Career Interest Questionnaire instrument and are overall interest in STEM Careers, perception of a supportive environment for pursuing a career in STEM, interest in pursuing educational opportunities that would lead to a career in STEM, and perceived importance of a career in science.

Primary Research Questions

1. What is the effect of a one semester STEM Lab course on middle school students' overall interest in STEM fields?
    a. What is the effect of a one semester STEM Lab course on middle school students' overall interest in science?
    b. What is the effect of a one semester STEM Lab course on middle school students' overall interest in technology?
    c. What is the effect of a one semester STEM Lab course on middle school students' overall interest in engineering?
    d. What is the effect of a one semester STEM Lab course on middle school students' overall interest in mathematics?
2. What is the effect of a one semester STEM Lab course on middle school students' interest in STEM careers?
    a. What is the effect of a one semester STEM Lab course on middle school students' interest in pursuing educational opportunities that could lead to a STEM career?

b. What is the effect of a one semester STEM Lab course on middle school students' perception of supportive environment for pursuing a career in STEM?

c. What is the effect of a one semester STEM Lab course on middle school students' perceived importance of a career in STEM?

3. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in STEM fields differ by gender?

    a. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in science differ by gender?

    b. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in technology differ by gender?

    c. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in engineering differ by gender?

    d. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in mathematics differ by gender?

4. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in STEM careers differ by gender?

a. Does the effect of a one semester integrated STEM Lab course on students' interest in pursuing educational opportunities that could lead to a STEM career differ by gender?

b. Does the effect of a one semester integrated STEM Lab course on students' perception of a supportive environment for pursuing a career in STEM differ by gender?

c. Does the effect of a one semester integrated STEM Lab course on students' perception of supportive environment for pursuing a career in STEM differ by gender?

Definition of Variables

Independent Variables—

1. Student completion of a one semester integrated STEM Lab course
2. Student gender

Dependent Variables

1. Overall student STEM interest
    (a) Student interest in science
    (b) Student interest in technology
    (c) Student interest in engineering
    (d) Student interest in mathematics
2. Student interest in pursuing a STEM career
    (a) Perception of a supportive environment for pursuing a career in STEM
    (b) Interest in pursuing educational opportunities that would lead to a career in STEM
    (c) Perceived importance of a career in science

Participants

Treatment Group—Students enrolled in STEM Lab course during fall 2015 semester

Comparison Group—Students of same age/grade level who were not enrolled in STEM Lab course and who had not previously completed the full semester STEM Lab course

Research location

All research was conducted at The Middle School in a designated small community approximately 30 miles outside the Kansas City metropolitan area. This school is a designated Title 1 school in a small rural town. The school enrollment is approximately 475 students. District and school officials were contacted, and approval for the study was obtained from the superintendent of the local district and the building principal. Teachers in the science department at the designated school agreed to allow the survey to be administered within their classes so that all students in the 7th and 8th grades would be given the opportunity to participate in the survey. Permissions and survey announcements were distributed through the science classes at the school. Science classes were selected as the ideal course for survey deployment because all 7th and 8th grade students are enrolled in a science course, and the science teachers were familiar with the instrument and had used the instrument in the past.

Research time period

Research was completed during the fall 2015 semester.

August 2015—all participating 7th and 8th grade students completed the baseline survey during their science class.

August-December—Students completed courses as regularly scheduled. Students in the treatment group were enrolled in the integrated STEM lab course, and students in the comparison group were NOT currently and had not previously been enrolled in the full semester STEM lab course.

January 2016—the survey instrument was administered as a post-test within the same courses after completion of the fall 2015 semester. Last minute scheduling changes by the administration at The Middle School prevented survey administration in December 2015 before the winter break as planned, but survey participants were surveyed upon return from the break in early January 2016.

Sampling methods

Treatment group—Participant group was composed of students assigned to the full semester STEM Lab course during fall 2015 semester. While completely random assignments was outside the researcher's control, the school's student data management system randomly assigns students to the STEM Lab course for one semester during their seventh or eighth grade year. All students are required to take the course, so the enrolled students in a given semester should provide a representative sample of the school population. Class sizes in the integrated STEM lab course were lower than anticipated during the fall 2015 semester due to temporary changes in staffing in other related arts courses at The Middle School. Also, permission to complete the survey was delayed by the district administration which prevented the researcher from obtaining parental consent for student study participation at the school's back to school event. Also because the study announcements and requests for consent could not be distributed until the first week of school, and it is necessary for the survey to be given very early in the semester to be considered a pre-test, some parental consents were not obtained in time for students to be included in the study groups. Expected $n \approx 80$. Actual $n=27$.

Comparison group—the comparison group was composed of students in 7th and 8th grades who have not completed the STEM Lab course at The Middle School. During the fall 2015 semester, approximately 120 seventh graders and 40 eighth graders would be enrolled at the given school and have not taken STEM Lab. Expected $n \approx 160$. Actual $n=45$. See above explanation within treatment group description for details on discrepancies between actual and expected sample sizes.

Procedures

The survey was administered within the 7th and 8th grade science courses at the designated school. This placement was determined due to two factors. All students at those grade levels must be enrolled in a science course, so all students had the opportunity to participate in the survey. Additionally, the teachers of those courses were moderately familiar with the study having administered it during a previous school year for another purpose.

The survey instrument was administered through the district's student information and data management system. This allowed for information security and accurate reporting of grade level and enrollment data. The survey and reporting of data was administered by the district's technology integration specialist. Survey data reports were stored securely within the district's password protected server and computer system, and any printed reports were securely stored when not in use.

Data was analyzed using SPSS and applying techniques for two-way MANOVA. Significance was determined at the $p < .05$ level.

Two-way MANOVA was required due to the existence of two independent variables and two dependent variables. MANOVA procedures account for more Type 1 error than processing the data with multiple ANOVAs or t-tests. Any results for Wilks's lambda that were determined to be significant, were subjected to post-hoc analysis conducted using the Bonferroni method. See chapter 4 for additional details on results and analysis.

Survey Instrument

The STEM Semantics Survey and the STEM Career Interest Questionnaire are two instruments designed to assess perceptions of Science, Technology, Engineering, and Mathematics (STEM) disciplines. The survey was developed by researchers completing an NSF funded project called the Innovative Technology Experiences for Students and Teachers. The primary goal of ITEST is “to seek solutions to help ensure the breadth and depth of the Science, Technology, Engineering, and Mathematics (STEM) workforce” (Tyler-Wood, Knezek, & Christensen, 2010). Researchers conducting ITEST projects must find or develop instruments, methods, and procedures for assessing and predicting student inclination to participate in STEM fields in order to determine overall effectiveness of planned and implemented projects. In order to meet this challenge, the Middle Schoolers Out to Save the World (MSOSW) ITEST project dedicated the first year of their NSF grant project to develop valid and reliable instruments to assess interest in STEM fields and STEM careers. The outcome of interest in this project was student STEM career interest. However, with a project length of three years, it was not possible for researchers to follow students in a longitudinal study to determine future college degrees and careers of project participants. Therefore, researchers developed two sister instruments. The STEM Semantics survey assesses student interest in STEM fields of science, technology, engineering, and mathematics as well as a short career interest section, and the Career Interest Questionnaire measures interest in STEM or science careers.

The STEM Semantics Survey is a 25-item instrument that measures interest in science, technology, engineering, and mathematics with a short general career interest section. The Career Interest Questionnaire (CIQ) is a 12-item instrument that measures interest in STEM or science careers. The original Career Interest Questionnaire was written to determine interest in science careers, but researchers determined that it could be equally effective in determining interest in

STEM careers by changing instrument references to science and science careers to STEM and STEM careers or any particular discipline within the STEM family of subjects.

These instruments were ideal for the current project due to their specific design for use with middle school students and their intent to measure changes in interest over a shorter period of time such as a semester or yearlong project. Researchers designing the ITEST project found a limited number of survey instruments available for use in measuring STEM interest and STEM career interest. Of the available instruments, most were unsuitable due to the intended age of participants, due to dated questions, due to focus on general career interest rather than STEM careers, or due to specific focus on an individual STEM content area such as science.

The STEM Semantics Survey and the Career Interest Questionnaire have been deemed valid with similar demographics to the study school. One of the validation sample sites for the ITEST project was 6^{th}-8^{th} grade students in a relatively small, rural school system with a majority white population and 10% low SES as determined by free and reduced lunch status. The survey instrument was also deemed valid in a school system with a broader variety of socioeconomic diversity (Tyler-Wood et al., 2010). These diverse samples were selected to ensure the instruments would function well for all demographics that would be encountered through the 19 diverse sites selected for the MSOSW project.

Data was obtained from two classes of middle school students across four areas: STEM semantics, career interest, technology attitudes, and learning dispositions. Reliability and validity for technology attitudes and learning dispositions were previously established for middle school age students, so the MSOSW researchers could focus on analyzing the STEM Semantics Survey and Career Interest Questionnaire. Data was collected through a combination of an online data acquisition system and paper pencil surveys to meet the needs of individual project sites.

The STEM Semantics Survey was adapted from Knezek and Christiansen's 1998 Teacher's Attitudes Toward Information Technology Questionnaire (TAT) which was derived from earlier Semantics Differential research by Zachikowsky in 1985. The TAT included 10 adjective pairs. The most consistent five were incorporated as target statement descriptors reflecting perceptions of each separate field of science, technology, engineering, and mathematics as well as a fifth scale regarding STEM careers. Students select their level of identification with each adjective pair along the continuum with a scale from 1-7. Some items within each subsection are reverse coded and all adjective pairs are given in different order within each subsection.

The Career Interest Questionnaire is a Likert-type instrument composed of 12 items on three subscales measuring the following constructs: perceptions of a supportive environment for pursuing a career in STEM, interest in pursuing educational opportunities that would lead to a career in STEM, and perceived importance of pursuing a career in STEM. It was adapted from a longer instrument developed by Bowditch for a Native Hawaiian Studies project focusing on STEM. Adaptations were based on analysis by Bowditch with permission.

Internal consistency reliabilities for the combined groups (n=174) on STEM Semantics Survey perceptions of science, mathematics, engineering, technology, and STEM as a career ranged from Alpha = .84 to Alpha = .93. These numbers are in the range of very good to excellent.

Internal Consistency Reliabilities for STEM Semantics Survey Scales

Scale	**Number of Items**	**Alpha**
Science	5	.84
Math	5	.88
Engineering	5	.92
Technology	5	.91
STEM Career	5	.93

Cronbach's alpha (n=60) for individual scales on the Career Interest Questionnaire ranged from .78 to .94 across the constructs represented. These values fall within the range of respectable to excellent.

Internal Consistency Reliabilities for Career Interest Scales

Scale	**Number of Items**	**Alpha**
Perception of supportive environment for pursuing a career in STEM	4	.86
Interest in pursuing educational opportunities that would lead to a career in science	5	.94
Perceived importance of a career in science	3	.78
All items	12	.94

The STEM Semantics Survey and Career Interest Questionnaire were reviewed and revised by the project team and members of the project advisory committee. The main revisions to the STEM Semantics Survey were to ensure the instructions and vocabulary would be understood by students as young as sixth grade. The Career Interest Questionnaire uses only the well-validated items from the Bowditch 2009 study even when that meant having a small number of items per construct.

Exploratory factor analyses were completed on the 2009 data. The results of these analyses indicated that in every case, the items loaded on the hypothesized factors. Items targeting semantic perception of individual STEM fields and STEM career interest were most strongly associated with the intended construct in every case. The items targeted for assessing the three factors in the Career Interest Questionnaire were also most strongly associated with the intended construct. For full details see Tyler-Wood et al. (2010).

Discriminant validity was also examined for the five groups who participated in the STEM Semantics Survey pilot groups. These groups included:

1. Grade 6-8 students (n=60)
2. Teacher/Liaison participants in MSOSW summer training (n=11)
3. Teacher preparation candidates enrolled in technology integration course (n=58)
4. NSF ITEST Project Principal Investigators and Evaluators (n=29)
5. Technology Teacher Educators (faculty) Attending SITE conference (n=14)

Perceptions of ITEST PIs and evaluators, technology teacher educators, and MSOSW teachers were higher than teacher preparation candidates or MSOSW middle school students. Because of identified career paths of the ITEST project team were highest in regards to engineering. Technology educators were highest in regards to perceptions of technology, and mathematics and science middle school teachers had the most positive perceptions of mathematics and science when focus was restricted to specific disciplines. When all faculty/adults were combined, the composite group was significantly higher than then pre-service teacher candidates in all areas ($p < .003$). Middle school students were lower than all groups with STEM professional positions in all measures except mathematics and engineering where their scores were similar to technology educators. These results indicate that the STEM Semantics Survey is capable of measuring stable psychological constructs with sufficient consistency to assess changes in perceptions resulting from project activities (Tyler-Wood et al., 2010).

Because the Career Interest Questionnaire is only appropriate for administration to middle school students, cross-group validity analysis was not possible. Correlations between total score from the Likert-type items and other learner disposition scales completed by students were examined to determine criterion-related validity. STEM Career interest was positively correlated with Creative Tendencies ($r=.53$, $p<.0005$), Computer Importance (for schooling and career) ($r=.54$, $p<.0005$), Motivation ($r=.42$, $p<.0001$), and Attitude toward School ($r=.42$, $p<.0001$). This trend was true for the group as a whole ($n=60$) and for each individual class. These data indicate that STEM Career Interest Questionnaire scores are positively associated with established measures in the direction anticipated (Tyler-Wood et al., 2010).

Assumptions

There are three basic assumptions necessary for conducting a MANOVA. First, it is assumed that the data is randomly sampled from a population with a normal distribution and scores are independent. Second, it is assumed that the dependent variables are normally distributed for each population. Thirdly, the population variances among the dependent variables are the same across all levels of the factor (Green & Salkind, 2008)

Limitations

The sample for this study was limited due to the unique nature of the course. The majority of students in this school are Caucasian with low sample sizes on minority groups that make it ineffective to disaggregate results for ethnic groups. Further study on this topic would be prudent in more diverse schools that develop similar integrated STEM courses.

Due to the situation of this course within an already established school setting, the researcher did not have the opportunity for true randomized assignment to the study groups. However, the information management system used by the school district completes the scheduling based on set criteria entered in advance. Since all students will take the integrated STEM course if they are at the school for both 7th and 8th grades, a nearly randomized situation is achieved. The study must still be considered quasi-experimental, but due to the computerized scheduling, the randomization component necessary for a truly experimental study is nearly met since students randomly assigned to the course in the given semester were compared to those who have not taken the course. 8th grade students who took the course during the previous year as 7th graders were excluded from the results.

Chapter 4: Data Analysis and Findings

Introduction to the Findings

The STEM movement has been brought to the forefront with a sense of urgency in recent years. Recommendations have been set forth to develop integrated STEM courses to allow students an opportunity to explore STEM subjects and careers as part of an integrated whole rather than as distinctly separate subjects. Due to the costs and barriers to implementation of these types of courses, it is desirable to examine the effectiveness of these programs as change agents in student interest and attitudes toward STEM subjects and STEM careers. This chapter examines the results of the study implemented by the researcher in the fall of 2015 at The Middle School where an integrated STEM lab course is a required elective for all students. The chapter is organized with an overview of sample characteristics followed by an examination of the data gathered to answer each of the previously stated research questions.

Sample Characteristics

Students involved in the study are enrolled in the 7th or 8th grades at The Middle School. Pre-test surveys were completed by 109 students, and 100 students completed the post-test survey. Comparison group participants (n=45) have not participated in the integrated STEM course as of the semester the study was conducted. Treatment group participants (n=27) were enrolled in the integrated STEM course during the study semester. 47 students were eliminated from the results due to not having completed both the pre-test and post-test surveys (n=9) or having completed the integrated STEM lab course in a previous semester (n=38). Within the comparison group, 26 participants were female and 19 participants were male. In the treatment group, 14 participants were female and 13 participants were male. There were not sufficient numbers of students in minority categories to justify disaggregation of data.

Research Question 1

What is the effect of a one semester STEM Lab course on middle school students' overall interest in STEM fields?

A statistically significant change in interest in STEM fields (F=2.857, p=.022) was observed among students who completed the survey. However, students enrolled in the integrated STEM lab course were not found to respond in a statistically significant manner from the comparison group (F=1.333, p=.263). Although examination of univariate results on subscales are often not examined after an overall lack of statistical significance is observed, the subscales on the instrument administered to students can be used as independent measures of interest in the individual STEM fields, so the researcher continued with examination of the univariate results to determine if any subscales yielded significant differences. Results of these univariate analyses are examined in the subquestion sections that follow.

a. What is the effect of a one semester STEM Lab course on middle school students' overall interest in science?

   A statistically significant change in science interest ($F=5.321$, $p=.024$) was observed among students who completed the survey. However, students enrolled in the integrated STEM lab course were not found to respond in a statistically significant manner from the comparison group ($F=1.021$, $p=.316$). Also, when using the univariate results when following up after conducting a MANOVA, the Bonferroni method should be applied which would require significance at the $p=.0125$ level which was not achieved on the science subscale for the entire sample or when examining the differences between the control and treatment groups.

b. What is the effect of a one semester STEM Lab course on middle school students' overall interest in technology?

   No statistically significant differences in technology interest were observed between the experimental and comparison groups ($F=.263$, $p=.610$).

c. What is the effect of a one semester STEM Lab course on middle school students' overall interest in engineering?

No statistically significant differences in engineering interest were observed between the experimental and comparison groups (F=.644, p=.425).

d. What is the effect of a one semester STEM Lab course on middle school students' overall interest in mathematics?

No statistically significant differences in mathematics interest were observed between the experimental and comparison groups (F=.092, p=.763).

Research Question 2

What is the effect of a one semester STEM Lab course on middle school students' interest in STEM careers?

Student interest in STEM careers did not differ in a statistically significant manner between the experimental and comparison groups (F=.002, p=.963). Although examination of univariate results on subscales are often not examined after an overall lack of statistical significance is observed, the subscales on the instrument administered to students can be used as independent measures of interest in STEM careers, so the researcher continued with examination of the univariate results to determine if any subscales yielded significant differences. Results of these univariate analyses are examined in the subquestion sections that follow.

a. What is the effect of a one semester STEM Lab course on middle school students' interest in pursuing educational opportunities that could lead to a STEM career?

   Student interest in pursuing educational opportunities that could lead to a STEM career did not differ in a statistically significant manner between the treatment and experimental groups (F=.351, p=.555).

b. What is the effect of a one semester STEM Lab course on middle school students' perception of supportive environment for pursuing a career in STEM?

   Student perception of a supportive environment that could lead to a STEM career did not differ in a statistically significant manner between the treatment and experimental groups (F=.024, p=.878).

c. What is the effect of a one semester STEM Lab course on middle school students' perceived importance of a career in STEM?

   Student perception of the importance of a STEM career did not differ in a statistically significant manner between the treatment and experimental groups (F=.223, p=.638).

Research Question 3

Does the effect of a one semester integrated STEM Lab course on students' level of interest of in STEM fields differ by gender?

Overall interest in STEM fields did not differ in a statistically significant manner between the two gender groups (F=1.631, p=.166).

a. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in science differ by gender?
   Student interest in science did not differ in a statistically significant manner between the two gender groups (F=1.698, p=.197).
b. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in technology differ by gender?
   Student interest in technology did not differ in a statistically significant manner between the two gender groups (F=.787, p=.379).
c. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in engineering differ by gender?
   Student interest in engineering did not differ in a statistically significant manner between the two gender groups (F=.781, p=.380)
d. Does the effect of a one semester integrated STEM Lab course on students' level of interest of in mathematics differ by gender?
   Student interest in mathematics did not differ in a statistically significant manner between the two gender groups (F=.000, p=1.000)

Research Question 4

Does the effect of a one semester integrated STEM Lab course on students' level of interest of in STEM careers differ by gender?

Overall student interest in STEM careers did not differ in a statistically significant manner between groups ($F=.155$, $p=.857$). Although examination of univariate results on subscales are often not examined after an overall lack of statistical significance is observed, the subscales on the instrument administered to students can be used as independent measures of interest in STEM careers, so the researcher continued with examination of the univariate results to determine if any subscales yielded significant differences between gender groups. Results of these univariate analyses are examined in the subquestion sections that follow.

a. Does the effect of a one semester integrated STEM Lab course on students' interest in pursuing educational opportunities that could lead to a STEM career differ by gender?

   Student interest in pursuing educational opportunities that could lead to a STEM career did not differ in a statistically significant manner between gender groups ($F=.025$, $p=.875$).

b. Does the effect of a one semester integrated STEM Lab course on students' perception of a supportive environment for pursuing a career in STEM differ by gender?

   Student perception of a supportive environment for pursuing a career in STEM did not differ in a statistically significant manner between gender groups ($F=.008$, $p=.929$).

c. Does the effect of a one semester integrated STEM Lab course on students' perception of supportive environment for pursuing a career in STEM differ by gender?

   Student perception of a supportive environment for pursuing a career in STEM did not differ in a statically significant manner between gender groups (F=.164, p=.687).

Descriptive Statistics

When examining the descriptive statistics obtained from the survey results, it becomes apparent that the lack of statistical significance is accompanied by a lack of practical significance as well. When pre- and post- test scores are examined, most categories have means that do not change by more than one or two points. The descriptive statistics below for the overall groups as well as separated out by treatment and comparison groups demonstrate that the intervention measure did not lead to significant differences in results.

Table 1
Descriptive Statistics for All Respondents

Descriptive Statistics All Respondents

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Science Pre-test Score	72	18.00	11.00	29.00	20.0972	4.95944	24.596
Science Post-test Scores	72	20.00	10.00	30.00	21.4583	5.55875	30.900
Technology Pre-test Score	69	21.00	8.00	29.00	23.3768	5.53093	30.591
Technology Post-test Score	70	18.00	12.00	30.00	22.9429	5.74049	32.953
Mathematics Pre-test Score	72	21.00	8.00	29.00	19.4444	5.93127	35.180
Mathematics Post-test Score	72	19.00	10.00	29.00	21.2083	5.94325	35.322
Engineering Pre-test Score	72	23.00	12.00	35.00	19.4861	4.95897	24.591
Engineering Post-test Score	72	22.00	13.00	35.00	20.7361	5.21372	27.183
STEM Interest Pre-test Score	69	75.00	61.00	136.00	102.2464	19.79335	391.777
STEM Interest Post-test Score	70	71.00	70.00	141.00	103.7143	16.53117	273.280
STEM Career Interest Pre-test Score	72	48.00	12.00	60.00	39.3333	9.99014	99.803
STEM Career Interest Post-test Score	72	47.00	13.00	60.00	38.9444	11.10372	123.293
Career Support Pre-test Score	72	16.00	4.00	20.00	12.6111	3.43780	11.818
Career Support Post-test Score	72	16.00	4.00	20.00	12.6528	3.91516	15.328
Career Education Pre-test Score	72	20.00	5.00	25.00	16.0833	4.86653	23.683
Career Education Post-test Score	72	20.00	5.00	25.00	16.1389	4.79820	23.023
Career Importance Pre-test Score	72	12.00	3.00	15.00	10.6389	2.59634	6.741
Career Importance Post-test Score	72	12.00	3.00	15.00	10.1528	3.06576	9.399

Table 2 Descriptive Statistics for Treatment Group

Descriptive Statistics Treatment Group Only

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Science Pre-test Score	27	18.00	11.00	29.00	18.7778	5.07887	25.795
Science Post-test Scores	27	19.00	10.00	29.00	21.2222	5.81334	33.795
Technology Pre-test Score	27	20.00	9.00	29.00	18.7037	5.31916	28.293
Technology Post-test Score	27	19.00	10.00	29.00	20.3704	5.72544	32.781
Mathematics Pre-test Score	27	17.00	12.00	29.00	18.8889	5.11659	26.179
Mathematics Post-test Score	27	22.00	13.00	35.00	20.1111	5.75348	33.103
Engineering Pre-test Score	27	18.00	11.00	29.00	22.3704	6.28887	39.550
Engineering Post-test Score	25	18.00	12.00	30.00	21.4400	6.00056	36.007
STEM Interest Pre-test Score	27	13.00	5.00	18.00	11.8889	3.04243	9.256
STEM Interest Post-test Score	27	13.00	7.00	20.00	11.7778	3.84641	14.795
STEM Career Interest Pre-test Score	27	20.00	5.00	25.00	15.4444	5.31568	28.256
STEM Career Interest Post-test Score	27	19.00	5.00	24.00	15.0000	4.99230	24.923
Career Support Pre-test Score	27	11.00	4.00	15.00	10.1481	2.64144	6.977
Career Support Post-test Score	27	12.00	3.00	15.00	9.4444	3.20256	10.256
Career Education Pre-test Score	27	60.00	70.00	130.00	98.6296	19.41084	376.781
Career Education Post-test Score	25	61.00	70.00	131.00	99.7200	17.40814	303.043
Career Importance Pre-test Score	27	44.00	14.00	58.00	37.4815	10.21827	104.413
Career Importance Post-test Score	27	43.00	15.00	58.00	36.2222	11.49024	132.026

Table 3 Descriptive Statistics for Comparison group

Descriptive Statistics Comparison group Only

	N	Minimum	Maximum	Mean	Std. Deviation
Science Pre-test Score	45	12.00	29.00	20.8889	4.76837
Science Post-test Scores	45	10.00	30.00	21.6000	5.46227
Technology Pre-test Score	45	8.00	29.00	19.8889	6.28571
Technology Post-test Score	45	10.00	29.00	21.7111	6.07761
Mathematics Pre-test Score	45	12.00	35.00	19.8444	4.88484
Mathematics Post-test Score	45	13.00	30.00	21.1111	4.89073
Engineering Pre-test Score	42	8.00	29.00	24.0238	4.95584
Engineering Post-test Score	45	12.00	29.00	23.7778	5.48091
STEM Interest Pre-test Score	45	4.00	20.00	13.0444	3.61786
STEM Interest Post-test Score	45	4.00	20.00	13.1778	3.90390
STEM Career Interest Pre-test Score	45	5.00	25.00	16.4667	4.59545
STEM Career Interest Post-test Score	45	5.00	25.00	16.8222	4.59886
Career Support Pre-test Score	45	3.00	15.00	10.9333	2.55307
Career Support Post-test Score	45	3.00	15.00	10.5778	2.93481
Career Education Pre-test Score	42	61.00	136.00	104.5714	19.91708
Career Education Post-test Score	45	79.00	141.00	105.9333	15.78463
Career Importance Pre-test Score	45	12.00	60.00	40.4444	9.79693
Career Importance Post-test Score	45	13.00	60.00	40.5778	10.66108

Chapter 5: Conclusions

Introduction

The purpose of this study was to determine if students who complete the integrated STEM Lab course at The Middle School have higher levels of interest in STEM fields of science, mathematics, engineering, and technology than their same age peers who have not completed the course. Both an overall interest in STEM and interest in the individual fields of science, technology, engineering, and mathematics were examined. This study is also designed to determine if students who have completed the course have higher levels of interest in pursuing STEM careers and perceptions related to STEM careers.

This study also examined the effect of gender on the interest in STEM fields and careers. According to current literature and historical evidence, female students are significantly less likely to pursue STEM careers. While there are a variety of reasons for this suggested in the literature, this study focused on the difference between the results for male and female students rather than on the reasons for the differences.

Study Design

This study used repeated measures 2x2 factorial MANOVA design. The STEM Semantics Survey and the STEM Career Interest Questionnaire, developed at University of Texas as part of the ITEST initiative, were used as the measurement instruments. The instruments were administered as a pretest at the beginning of the fall 2015 semester and as a posttest after the fall 2015 semester. Students enrolled in the STEM Lab course during the fall 2015 semester served as the treatment group and students who had not previously taken the STEM Lab course and were not currently enrolled in the course served as the comparison group. MANOVA was the most appropriate type of analysis since the literature indicates that the variables chosen should be highly correlated.

Due to the inclusion of gender and course completion as the two independent variables and multiple dependent variables, a two way repeated measures mixed MANOVA analyses was run on the data. The design of the first analysis was a 2x2 factorial with two levels of gender and two levels of treatment. The dependent measures are overall interest in STEM fields, interest in science, interest in mathematics, interest in technology, and interest in engineering as measured by the STEM Semantics Survey.

A second analysis repeated the procedures using two levels of gender and two levels of course completion as the independent variables, but the dependent variables were based off the Career Interest Questionnaire instrument and were overall interest in STEM Careers, perception of a supportive environment for pursuing a career in STEM, interest in pursuing educational opportunities that would lead to a career in STEM, and perceived importance of a career in science.

Sample Characteristics

Students involved in the study were enrolled in the 7th or 8th grades at The Middle School. Pre-test surveys were completed by 109 students, and 100 students completed the post-test survey. Comparison group participants (n=45) have not participated in the integrated STEM course as of the semester the study was conducted. Treatment group participants (n=27) were enrolled in the integrated STEM course during the study semester. 47 students were eliminated from the results due to not having completed both the pre-test and post-test surveys (n=9) or having completed the integrated STEM lab course in a previous semester (n=38). A nearly even mixture of males and females participated in the surveys for the study. Within the comparison group, 26 participants were female and 19 participants were male. In the treatment group, 14 participants were female and 13 participants were male.

Research Question 1

What is the effect of a one semester STEM Lab course on middle school students' overall interest in STEM fields?

A statistically significant change in interest in STEM fields ($F=2.857$, $p=.022$) was observed among students who completed the survey. However, students enrolled in the integrated STEM lab course were not found to respond in a statistically significant manner from the comparison group ($F=1.333$, $p=.263$). Although examination of univariate results on subscales are often not examined after an overall lack of statistical significance is observed, the subscales on the instrument administered to students can be used as independent measures of interest in the individual STEM fields, so the researcher continued with examination of the univariate results to determine if any subscales yielded significant differences. Results of these univariate analyses are examined in the subquestion sections that follow.

A statistically significant change in science interest ($F=5.321$, $p=.024$) was observed among students who completed the survey. However, students enrolled in the integrated STEM lab course were not found to respond in a statistically significant manner from the comparison group ($F=1.021$, $p=.316$). Also, when using the univariate results when following up after conducting a MANOVA, the Bonferroni method should be applied which would require significance at the $p=.0125$ level which was not achieved on the science subscale for the entire sample or when examining the differences between the control and treatment groups. No statistically significant differences in technology interest ($F=.263$, $p=.610$), engineering interest ($F=.644$, $p=.425$), or mathematics interest were observed between the experimental and comparison groups ($F=.092$, $p=.763$).It was observed that the science interest subscale yielded a statistically significant change over time, but the results were not different for the treatment and experimental groups. This leads the researcher to question the reason for these differences. The fall 2015 semester was the first semester for full implementation of the Next Generation Science Standards (NGSS) as the curricular framework at the school where the survey data was collected. The NGSS are designed in a manner that encourages integration of engineering, technology, and mathematics within the science classroom which may explain some of the change in science interest and lack of difference between control and experimental groups. The school also implemented a new science curriculum series that has a significantly increased technology and engineering component and many new lab components. While it is not known if these factors affected any of the results, it leads the researcher to new questions about potential factors that could lead to potential interactions in the results.

Research Question 2

Student interest in STEM careers did not differ in a statistically significant manner between the experimental and comparison groups ($F=.002$, $p=.963$). Although examination of univariate results on subscales are often not examined after an overall lack of statistical significance is observed, the subscales on the instrument administered to students can be used as independent measures of interest in STEM careers, so the researcher continued with examination of the univariate results to determine if any subscales yielded significant differences. Results of these univariate analyses are examined in the subquestion sections that follow. Student interest in pursuing educational opportunities that could lead to a STEM career did not differ in a statistically significant manner between the treatment and experimental groups (F=.351, p=.555). Students at the 7th and 8th grade level are beginning to examine potential higher education opportunities and careers, but they often do not have set ideas about what they want in a college degree or career a decade in the future. Also the questions that are posed in the instrument require students to have a great deal of certainty and self-efficacy in their future choices. The questions are phrased in a manner that requires students to assert that they will successfully accomplish tasks rather than simply assessing student interest in potentially exploring those majors or careers. Student perception of a supportive environment that could lead to a STEM career did not differ in a statistically significant manner between the treatment and experimental groups (F=.024, p=.878). Since it would be unlikely that a student's participation in a course would change their family environment or level of support, and students are randomly scheduled into the course, it is reasonable that students in the two groups would not differ significantly in levels of family support. Student perception of the importance of a STEM career did not differ in a statistically significant manner between the treatment and experimental groups (F=.223, p=.638). The written curriculum for the integrated STEM course does not have a significant component on STEM career opportunities, so students may not have adequate information to base their responses upon. It would be helpful in future study to examine student knowledge of STEM careers and to include a teaching component on STEM career opportunities to inform students.

While significant differences were not noted between the experimental and comparison groups, and no statistically significant changes were noted in overall career interest or in career interest subscale categories, the researcher believes it is worthwhile to note that the means on all of these categories was above 3 on the 5 point scale indicating that on average, student interest is between the undecided and agree levels on the Likert scale. In future research, it could be helpful to conduct interviews with students whose responses were in the low, middle, and high ranges of interest and also to interview students whose levels of interest did not change and students whose interest changed significantly. When examining the questions in the category for level of support, two of the four items ask about family interest and encouragement. Since family interest and encouragement are unlikely to change based upon a course that the student takes, it logically follows that there would not be significant changes in the scores in this category. The researcher also believes that it would be worthwhile to examine what students know about STEM career options and what college majors would be included as STEM related fields. The educational category of the STEM career interest questionnaire begins with two questions about STEM interest related to college attendance and college majors. The researcher believes this may have led students to incorrectly assume that a college degree is required for all STEM careers. Examination of the curriculum and the instruction offered on STEM careers would also be of benefit in future studies. It is also worth noting that the changes observed overall were slight but not statistically significant decreases in interest. While the researcher did not predict a directional hypothesis for the research questions asked, this observation is surprising in light of the literature reviewed (Sadker & Sadker, 1994)and introduces new questions regarding why this course would cause students to be less interested in STEM careers.

Research Question 3

Overall interest in STEM fields did not differ in a statistically significant manner between the two gender groups (F=1.631, p=.166). Although examination of univariate results on subscales are often not examined after an overall lack of statistical significance is observed, the subscales on the instrument administered to students can be used as independent measures of interest in STEM careers, so the researcher continued with examination of the univariate results to determine if any subscales yielded significant differences between gender groups. Results of these univariate analyses are examined in the subquestion sections that follow. Student interest in science did not differ in a statistically significant manner between the two gender groups (F=1.698, p=.197). It can be noted from the graph of the student interest in science variable that female student interest in science appears to remain static while the male student interest increases, but these differences were not statistically significant. Student interest in technology did not differ in a statistically significant manner between the two gender groups (F=.787, p=.379). However, it is interesting to note that the graph of the results for technology interest shows that the two genders begin at a nearly identical data point, but male students' interest increases and female students' interest decreases throughout the intervention time period. Reasons for this phenomenon are unknown, but further research would be warranted on this topic. Student interest in engineering did not differ in a statistically significant manner between the two gender groups (F=.781, p=.380). Female students has higher engineering interest at the pre-test point and showed a slight increase in interest while male student interest was lower at the beginning of the semester and showed a more dramatic increase over time. Student interest in mathematics did not differ in a statistically significant manner between the two gender groups (F=.000, p=1.000). When examining the graph, the pre-test and post-test starting points are slightly different for the two gender groups, but the levels of increase are virtually identical over time. While there were not statistically significant differences between the gender groups, it is worth noting that when examining the graphs of the data, a trend can be seen between the genders. In science, technology, and engineering interest, male students are much more likely to demonstrate increases in interest. Female students' scores remain nearly static or decrease across the intervention time frame.

Figure 4 Science Interest by Gender

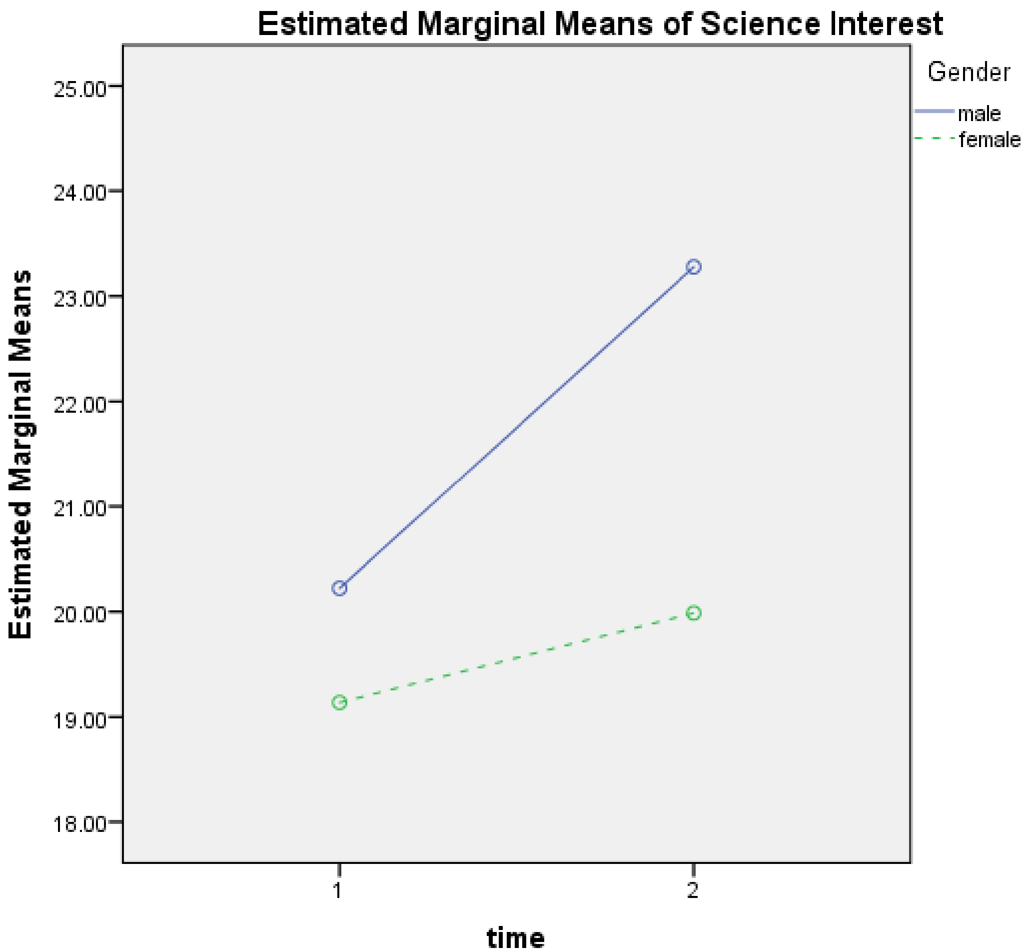


Figure 5 Technology Interest by Gender

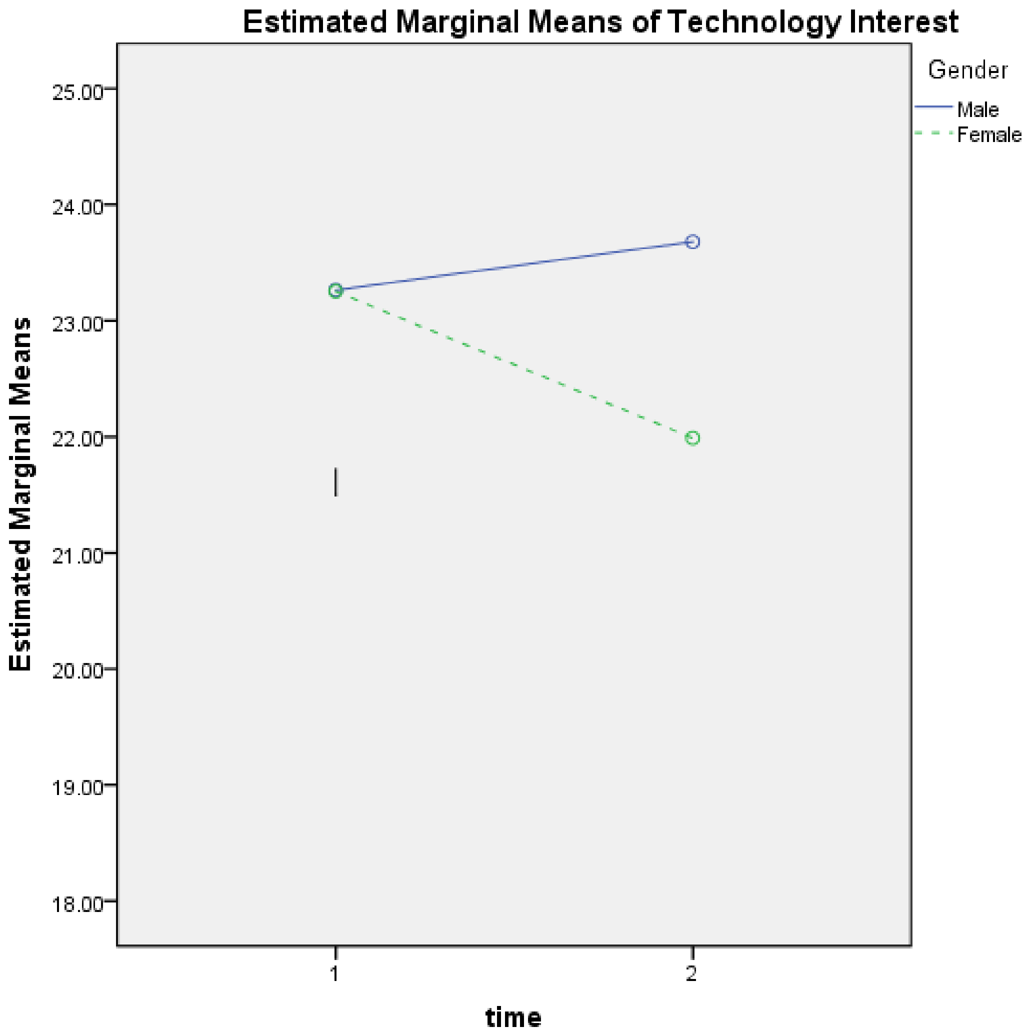


Figure 6 Engineering Interest by Gender

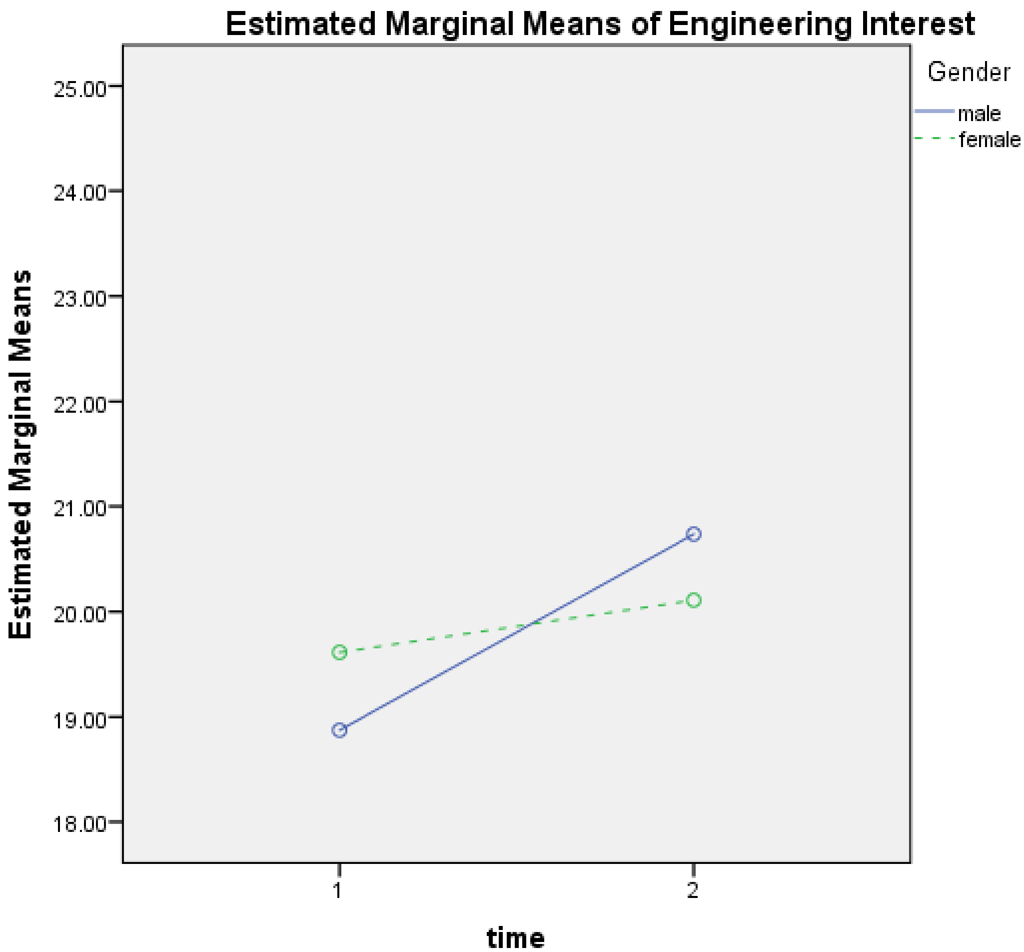
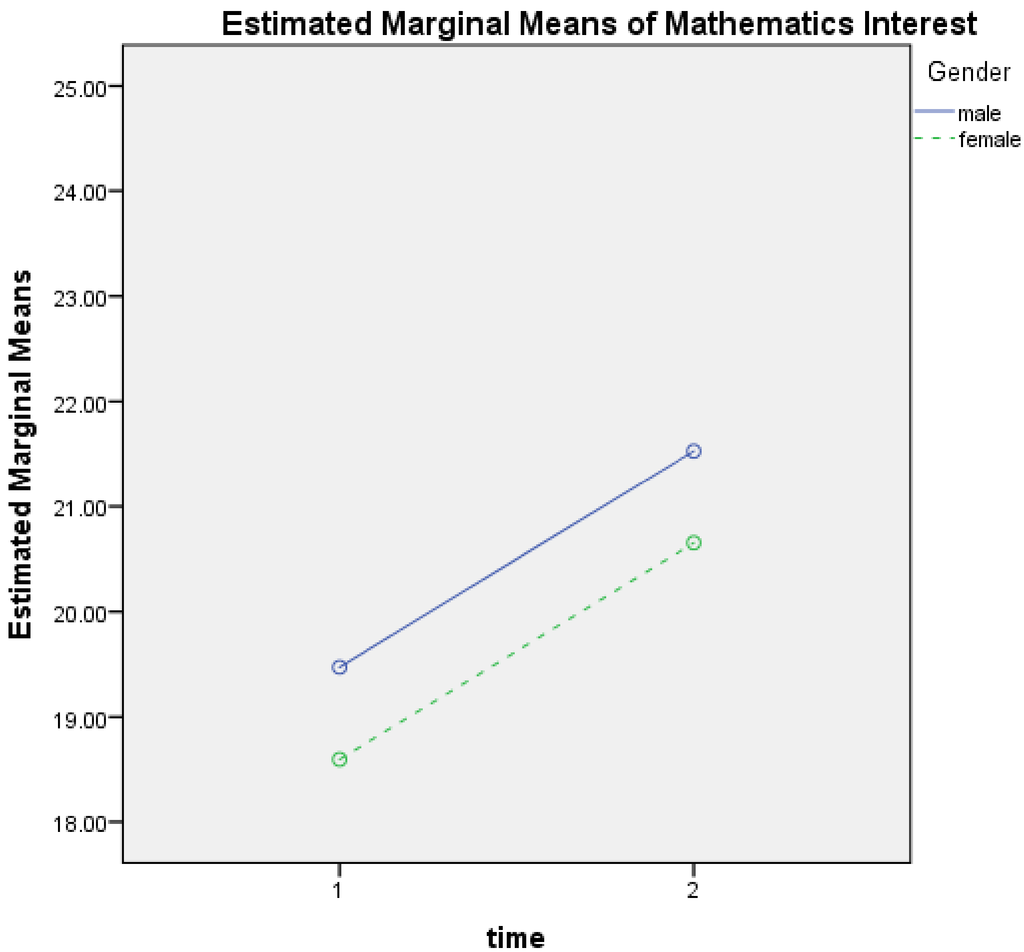


Figure 7 Mathematics Interest by Gender



Research Question 4

Overall student interest in STEM careers did not differ in a statistically significant manner between groups (F=.155, p=.857). Although examination of univariate results on subscales are often not examined after an overall lack of statistical significance is observed, the subscales on the instrument administered to students can be used as independent measures of interest in STEM careers, so the researcher continued with examination of the univariate results to determine if any subscales yielded significant differences between gender groups. Results of these univariate analyses are examined in the subquestion sections that follow. Student interest in pursuing educational opportunities that could lead to a STEM career did not differ in a statistically significant manner between gender groups ($F=.025$, $p=.875$). Concerns with the results from interest in educational opportunities when examining results by gender are similar to those that exist with interest in educational opportunities by test group. Students at this level have not made definitive choices about careers and higher education, and many students are just beginning to explore their future possibilities. It would be unlikely that the majority of middle school students would be able to make a certain decision about their education and career opportunities that might be a decade in the future. Student perception of a supportive environment for pursuing a career in STEM did not differ in a statistically significant manner between gender groups ($F=.008$, $p=.929$). This raises questions regarding the claims that female students feel less supported in STEM fields. In further study, it would be appropriate to assess whether this occurs at a later age or whether this perceived bias has been partially mitigated. Student perception of the importance of a career in STEM did not differ in a statically significant manner between gender groups ($F=.164$, $p=.687$). As discussed in the earlier examination of the data on this question by groups, this leads to additional questions regarding student understanding of STEM careers.

Descriptive Statistics

When examining the descriptive statistics obtained from the survey results, it becomes apparent that the lack of statistical significance is accompanied by a lack of practical significance as well. When pre- and post- test scores are examined, most categories have means that do not change by more than one or two points. When considering the time and expense that are required to implement an integrated lab-based STEM course, it is important to be certain that the course is serving the intended purpose. While this study cannot be considered a definitive answer to the value or importance of integrated STEM courses, the lack of results with statistical or practical significance in this study brings important questions to the forefront. In future study, examination of the results of these types of courses should be expanded to a wider demographic and examined over a longer period of time. Many of the questions asked require students to have plans for future careers (Tyler-Wood et al., 2010) which may not be a reasonable expectation for students at the middle school level (Gibbons & Borders, 2010). A longitudinal study of student interest in STEM and STEM careers tracking student results throughout high school and beyond could lead to interesting results that may assist in determining the potential long term effect of integrated STEM courses (Berlin & White, 2012).

During the semester this study was conducted, the course was taught by a new teacher who had previous science teaching experience, but she had not taught integrated STEM, and she was also new to the school. This change in teachers was not anticipated when the study was planned. It is unknown if the change in teachers for the course had any effect on the results, but it is worth noting. In discussions with the new teacher of the course, she indicated that many students become frustrated with the engineering processes that are used within the course. Students often have difficulty due to the independent nature of the course where the student and a partner are expected to learn, research, and conduct experiments without significant assistance from the teacher. The students also struggle with not having one right answer for every problem that is presented, and they find some of the material challenging or difficult to comprehend. When students become frustrated, this may affect their levels of interest in STEM fields and STEM careers (Hansen, 2014).

Another potential confounding factor is the adoption of new science standards and new science curriculum at The Middle School. The Next Generation Science Standards (NGSS) were adopted by the district with expectations for implementation during the 2015-2016 school year. The NGSS contain expectations for more integration among the subjects of science, engineering, and mathematics. As a result of the new standards, the district also purchased a new science curriculum series for The Middle School that provides more opportunities for integration of engineering within the science classroom. This curriculum series was accompanied by materials kits that also add additional hands-on opportunities for the students. While the results of this study cannot determine whether or not this affected the student results, it is a consideration for further study.

While this study did not yield the significant results that many STEM proponents might desire, it does raise concerns about STEM education and lead to interesting new questions that can be researched. Previous research has indicated that integrated STEM courses should be effective in increasing student interest

(Brophy et al., 2008; Johnson, 2013; Morrison, 2006; National Academy of Engineering, 2009; Stohlmann et al., 2012), so additional research should be conducted to determine why results from this study differ from what is indicated in previous literature. Potential future research may focus on student interest in STEM in a more long-term manner. Following this cohort of students who all participated in the STEM course as they progress through high school and into college and beyond could yield interesting data about the lasting effects of this course. Also, it would be beneficial to examine the survey instrument used. Multiple questions on the career interest scales relate back to family support. Family support is unlikely to change based upon student participation in a particular course, so those questions may have skewed the results toward nonsignificance. Creation of a different instrument or further research into the questions on the instrument used might lead to better results on the actual effect of the course on student interest. Now that baseline data has been gathered, it could be beneficial to employ a mixed methods approach that would include interviews of students who provide responses in the high, low, and average categories of responses. Closer examination of the curriculum used with particular focus on what students are taught about STEM careers and the individual STEM fields.

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Appendix

Survey Instruments

STEM Semantics Survey

This five-part questionnaire is designed to assess your perceptions of scientific disciplines. It should require about 5 minutes of your time. Usually it is best to respond with your first impression, without giving a question much thought. Your answers will remain confidential.
Instructions: Choose one circle between each adjective pair to indicate how you feel about the object.

To me, SCIENCE is:									**Reverse Coded (RC)**
fascinating	①	②	③	④	⑤	⑥	⑦	mundane	RC
appealing	①	②	③	④	⑤	⑥	⑦	unappealing	RC
exciting	①	②	③	④	⑤	⑥	⑦	unexciting	RC
means nothing	①	②	③	④	⑤	⑥	⑦	means a lot	
boring	①	②	③	④	⑤	⑥	⑦	interesting	
To me, MATH is:									
boring	①	②	③	④	⑤	⑥	⑦	interesting	
appealing	①	②	③	④	⑤	⑥	⑦	unappealing	RC
fascinating	①	②	③	④	⑤	⑥	⑦	mundane	RC
exciting	①	②	③	④	⑤	⑥	⑦	unexciting	RC
means nothing	①	②	③	④	⑤	⑥	⑦	means a lot	
To me, ENGINEERING is:									
appealing	①	②	③	④	⑤	⑥	⑦	unappealing	RC
fascinating	①	②	③	④	⑤	⑥	⑦	mundane	RC
means nothing	①	②	③	④	⑤	⑥	⑦	means a lot	
exciting	①	②	③	④	⑤	⑥	⑦	unexciting	RC
boring	①	②	③	④	⑤	⑥	⑦	interesting	
To me, TECHNOLOGY is:									
appealing	①	②	③	④	⑤	⑥	⑦	unappealing	RC
means nothing	①	②	③	④	⑤	⑥	⑦	means a lot	
boring	①	②	③	④	⑤	⑥	⑦	interesting	
exciting	①	②	③	④	⑤	⑥	⑦	unexciting	RC
fascinating	①	②	③	④	⑤	⑥	⑦	mundane	RC
To me, a CAREER in STEM—science, technology, engineering, and/or mathematics (is):									
means nothing	①	②	③	④	⑤	⑥	⑦	means a lot	
boring	①	②	③	④	⑤	⑥	⑦	interesting	
exciting	①	②	③	④	⑤	⑥	⑦	unexciting	RC
fascinating	①	②	③	④	⑤	⑥	⑦	mundane	RC
appealing	①	②	③	④	⑤	⑥	⑦	unappealing	RC

Career Interest Questionnaire

This survey contains 3 brief parts. Read each statement and then mark the circle that best shows how you feel.

Instructions: **Select one level of agreement for each statement to indicate how you feel.**
SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

	SD	D	U	A	SA
1. I would like to have a career in STEM (Science, Technology, Engineering, and/or Mathematics).	①	②	③	④	⑤
2. My family is interested in the STEM (Science, Technology, Engineering, and/or Mathematics) courses I take.	①	②	③	④	⑤
3. I would enjoy a career in STEM (Science, Technology, Engineering, and/or Mathematics.	①	②	③	④	⑤
4. My family has encouraged me to study STEM (Science, Technology, Engineering, and/or Mathematics.	①	②	③	④	⑤
5. I will make it into a good college and major in an area needed for a career in STEM (Science, Technology, Engineering, and/or Mathematics.	①	②	③	④	⑤
6. I will graduate with a college degree in a major area needed for a career in STEM (Science, Technology, Engineering, and/or Mathematics.)	①	②	③	④	⑤
7. I will have a successful professional career and make substantial STEM contributions.	①	②	③	④	⑤
8. I will get a job in a STEM-related area.	①	②	③	④	⑤
9. Some day when I tell others about my career, they will respect me for doing STEM work.	①	②	③	④	⑤
10. A career in STEM (Science, Technology, Engineering, and/or Mathematics) would enable me to work with others in meaningful ways.	①	②	③	④	⑤
11. STEM workers make a meaningful difference in the world.	①	②	③	④	⑤
12. Having a career in STEM (Science, Technology, Engineering, and/or Mathematics) would be challenging.	①	②	③	④	⑤

Integrated STEM Course Module Descriptions & Objectives

CHEMICAL MATH OVERVIEW Are you curious how chemists determine what to put together and just what quantity to use when making things such as perfume or medicine? In Chemical Math, students see the math that chemists use on a daily basis. Students balance equations, solve inequalities, use scientific notation, and learn basic chemistry concepts. Students use Avogadro's number and create Lewis dot structures of atoms. In Chemical Math, the numbers behind chemistry are the focus.

STUDENT OBJECTIVES

• Locate melting points on a number line.

• Calculate and compare densities of different substances.

• Learn the structure of an atom and of the periodic table.

• Express sizes of atoms and atom components using scientific notation.

• Calculate atomic mass based on isotope percentages.

• Explore the mole concept and Avogadro's number.

• Translate and solve algebraic expressions involving masses and moles of substances.

• Explore and solve examples of one- and two-step equations used in chemistry.

• Evaluate serial dilutions using inequalities.

ACTIVITIES *Students complete three performance assessments: 1) Scientific Notation – explain the structure of an atom, show a number in correct scientific notation, convert a given number to scientific notation, and explain the use of scientific notation in chemistry; 2) Balancing Equations – define equation and give an example, explain chemical equations, and balance a given equation; and 3) Solving Equations – solve given equations, solve given inequalities, and explain the process of serial dilution.*

Engineering Towers OVERVIEW

Students utilize math, physics, and problem-solving skills in Engineering Towers. They are given a challenge to build a tower that will hold more weight than the towers built by their classmates. Designing, building, and testing a tower are the activity base in Engineering Towers. Using engineering skills and video segments, students learn the skills necessary to facilitate construction and evaluation of a tower.

STUDENT OBJECTIVES

• Use a worksheet to create and illustrate a specific design for a tower.

• Recognize the various types of forces that act on a structure.

• Transfer their designs to patterns.

• Differentiate between an engineer and an architect.

• Learn about the forces that act upon structures.

• Learn how towers strengthen other structures.

• Evaluate their finished towers on a testing device.

ACTIVITIES Students complete three performance assessments: 1) Designing Your Tower – sketch several different tower designs, demonstrate an understanding of diagonals and triangles through thumbnail sketches, and choose one of the sketches; 2) Making Your Pattern – demonstrate the ability to transfer a thumbnail sketch to a full-size drawing; and 3) Assembling Your Tower – complete towers and ensure the tower specifications were followed.

Flight Technology OVERVIEW

In *Flight Technology*, students learn the principles of flight. Students use a computer flight simulator to experience piloting an aircraft. Each student evaluates the other and prepares a written critique of his or her partner's flight. Students are introduced to navigation and plot a course using angular measurement and mathematical computation.

STUDENT OBJECTIVES

• Explore the basic principles of aerodynamics by operating a flight simulator.

• Design and construct an airfoil.

• Observe and understand Bernoulli's principle by using a wing tester device.

• Produce and measure lift on an airfoil.

• Use a navigation plotter to determine the direction and distance for a flight plan.

• Use flight simulator software to test determined calculations.

• Use computer software to examine the factors that change the value of lift.

ACTIVITIES

Students complete three performance assessments: 1) Basic Aerodynamics – identify Bernoulli's principle and the effect of velocity on pressure and the effects and factors of *stall, force, and lift of an airfoil; 2) Wing Testing – design, build, and test a wing using a wing tester; and 3) Navigation – demonstrate an understanding of how to calculate distance in nautical and statute miles and identify necessary tools during a flight.*

FORCES OVERVIEW

In *Forces*, students explore forces and how they affect the motion of objects. Students learn to describe and measure the motion of objects by completing distance, time, speed, and velocity measurement activities. Students use examples they already find relevant to learn about various forces. They describe and measure the changing motion of accelerating objects and observe the direction of motion and how radius affects centripetal acceleration.

STUDENT OBJECTIVES

• Calculate the force of gravity on a massive object in the metric unit of newtons.

• Experiment with balanced and unbalanced forces acting on an object.

• Observe a moving object and determine if the force acting on it is balanced or unbalanced.

• Explain the difference between speed and velocity.

• Experiment with and explain Newton's three laws of motion.

• Determine that all accelerating objects are experiencing an unbalanced force.

• Explain the difference between mass and weight.

• Learn that gravity is an attractive force between objects.

• Recognize and identify the presence of frictional forces in everyday activities.

ACTIVITIES

Students complete three performance assessments: 1) Speed and Velocity – use an air table, inclined ramp, and photogates to study objects moving at a nearly constant speed and velocity; 2) Acceleration – measure the changing motion of accelerating objects due to the force of gravity; and 3) Falling Objects – study Newton's three laws of motion to learn how gravity affects a variety of falling objects.

FORENSIC MATH OVERVIEW

In *Forensic Math*, students create a theory about how a car may have been damaged in a fictional high school parking lot. Students use triangulation and polar coordinates to specify locations of objects within a crime scene and create scaled scene drawings. Tire impressions, footprints, and crime scene photos are used to piece together students' theories. Students find functions describing given relationships, determine slope, and determine the equation of a line.

STUDENT OBJECTIVES

• Create rough sketches of a scene using two different measurement methods.

• Learn about scale and convert measurements using a given scale.

• Use a final sketch to calculate actual distances.

• Learn about anthropometry.

• Record and graph foot length, height, and arm span measurements.

• Use functions to predict a person's height.

• Use the slope-intercept formula to determine the function of a line.

• Use skid speed and turning diameter formulas to analyze evidence.

• Put together a report stating a theory of what happened.

ACTIVITIES

Students complete three performance assessments: 1) Functions and Equations – solve and graph an equation and use the vertical line test to determine if a relation is a function; 2) Slope – determine the slope of a line, explain the slope-intercept formula, and demonstrate its use; and 3) Final Theory – identify excluded suspects and persons of interest and provide evidence to support a theory.

GENETICS OVERVIEW

In *Genetics*, students learn genetics terminology and simulate breeding experiments similar to Gregor Mendel's. They construct models of chromosomes and DNA. Students create Punnett squares and determine probabilities of offspring given specific parent genotypes. They complete a dihybrid cross and a natural selection experiment.

STUDENT OBJECTIVES

• Learn genetics terminology and history.

• Model the structure of DNA and the processes of mitosis and meiosis.

• Explore dominant and recessive genes, genotypes and phenotypes, and sex-linkage.

• Use Punnett squares to show monohybrid and dihybrid crosses and calculate probabilities.

• Discuss the risks and benefits of genetic research.

• Explore the effects of natural selection on a simulated population.

ACTIVITIES

Students complete three performance assessments: 1) Genotype Dominance – distinguish between dominant and recessive and between genotype and phenotype using correct gene notation; 2) Incomplete Dominance – explain incomplete dominance and show how a Punnett square predicts probabilities; and 3) Dihybrid Cross – define dihybrid cross *and* sex-linked traits *and predict the offspring produced from a specific parent cross.*

GEOMETRIC PACKING OVERVIEW

In *Geometric Packing*, students explore surface areas and volumes of various objects by packing materials. They explore spatial relationships and tessellations by transformations and the use of mathematical software. Students are introduced to the concept of slope, have tactile explorations of spherical packing, and find applications of Pascal's Triangle. They use the Fibonacci sequence to understand the greatest common divisor and the least common multiple. Finally, they explore the Pythagorean Theorem by building a scale replica of the Pyramid of Giza.

STUDENT OBJECTIVES

• Discover surface areas and volumes of three-dimensional objects.

• Create tessellations by the use of rotations, reflections, and translations.

• Investigate spherical packing and the applications of Pascal's Triangle in packing.

• Use the golden ratio, greatest common divisor, and least common multiple to understand architecture and designs.

• Utilize ancient Egyptian mathematics to explore the golden ratio and the Pythagorean Theorem.

ACTIVITIES

Students complete three performance assessments: 1) Surface Areas, Volumes, and Applications – find the surface area and volume of standard objects, recite the Honeycomb Conjecture, and define tessellation*; 2) The Fibonacci Sequence and Pascal's Triangle – find Fibonacci sequences, distinguish the greatest common divisor and the greatest common factor, and build Pascal's Triangle; and 3) Rotations, Reflections,* *Translations, and Dilations – rotate, reflect, and translate a figure; identify the coordinates on a coordinate grid; and perform and explain dilations.*

HEAT & ENERGY OVERVIEW

In *Heat & Energy*, students learn definitions of concepts related to heat and energy, including temperature, potential and kinetic energies, and work. They look at heat and energy from the molecular viewpoint as they construct models of simple hydrocarbon fuels. Students learn the chemical reaction involved in combustion and the components necessary for combustion to occur, and they distinguish examples of exothermic and endothermic reactions.

STUDENT OBJECTIVES

• Describe how heat and light energy are capable of work.

• Express how molecular motion relates to temperature.

• Define and give examples of the first and second laws of thermodynamics.

• Classify different types of fuel sources.

• Contrast exothermic and endothermic reactions.

• Deduce that food is fuel.

• Conduct an experiment to evaluate the expansion properties of different materials.

ACTIVITIES

Students complete three performance assessments: 1) Hydrocarbon Molecules – build a methane molecule and a propane molecule and show a chemical bond and explain what it represents; 2) Heat Content – understand and explain the differences and similarities among specific heat, heat capacity, and heat content; and 3) Heat Expansion – study and explain heat expansion and use a compound bar to explain how a thermostat works.

LASER GEOMETRY OVERVIEW

In *Laser Geometry*, students use algebra and geometry to explore different mathematical concepts including exponents, scientific notation, angles, and waves. Students conduct experiments to investigate interior and exterior angles. Finally, they explore degrees of angles by using a game controller to create an inexpensive, interactive whiteboard and by manipulating the direction of laser beams to piggyback a radio signal to a receiver.

STUDENT OBJECTIVES

• Investigate types and properties of angles and triangles.

• Relate angle properties to parallel and perpendicular lines.

• Use exponents and scientific notation to represent numbers.

• Use and solve proportions in order to discover similar and congruent polygons.

• Use a compass and straightedge to create parallel and perpendicular lines, create triangles, and bisect angles.

ACTIVITIES

Students complete three performance assessments: 1) Angles – define angle of incidence *and* angle of reflection *and characterize properties of parallel lines cut by a transversal; 2) Triangles & Congruency – classify triangles by the measure of their internal angles, determine congruency, explore supplementary and complementary angles, and understand Heisenberg's Uncertainty Principle; and 3) Waves & Particles – explain how a photon acts as a wave and a particle, find the slope-intercept of a line, and explain the slopes of parallel and perpendicular lines.*

PLANTS & POLLINATION OVERVIEW

In *Plants & Pollination,* students fit plants into the five-kingdom classification system and learn the importance of plants on Earth. They are introduced to the structure and function of plant cells and tissues. They learn the functions of roots, stems, and leaves and cover plant processes including photosynthesis, respiration, and transpiration.

They also look at plant pollination and reproduction and the difference between monocots and dicots.

STUDENT OBJECT IVES

• Learn the five- and six-kingdom classification systems and place plants within them.

• Learn to use a microscope and observe prepared plant cells under the microscope.

• Prepare slides, observe living plant cells, and compare plant cells with animal cells.

• Germinate seeds and observe seed leaves of monocots and dicots.

• Learn the importance of plant pigments; extract pigments using chromatography.

• Using slides and models, identify structures of stems, roots, and leaves.

• Demonstrate the process of photosynthesis.

• Understand the importance of photosynthesis and the factors affecting it.

• Identify plant reproductive structures; learn how pollination occurs and its importance.

ACTIVITIES

Students complete three performance assessments: 1) Plant Structure – identify monocot and dicot seeds and identify plant organs and tissues; 2) Plant Reproduction – identify reproductive structures, explain purpose of fruits and seeds, and describe pollination; and 3) Photosynthesis – show and explain the setup for the photosynthesis experiment, explain the results, and give reactants and products of the photosynthesis equation.

POPULATION PERSPECTIVES OVERVIEW

Demography, the study of human populations, is very much a "numbers game." It illustrates connections between math and the real world and also provides an example of a career field in which math is not only important, but essential. In *Population Perspectives*, students learn about quadratic and exponential functions and polynomials and use these algebra concepts to solve population-related problems.

STUDENT OBJECTIVES

• Spotlight population growth in various countries.

• Solve problems by using population growth rate equations.

• Define and identify functions, including exponential growth and decay functions.

• Use the graphing calculator to graph exponential growth and decay functions.

• Construct and solve polynomials related to population characteristics.

• Define *quadratic equations* and solve them using several methods.

• Define *carrying capacity* and *demographic transition*.

• Review population problems in more- and less-developed countries.

• Make recommendations for dealing with future population growth.

ACTIVITIES

Students complete three performance assessments: 1) Exponential Growth – contrast linear and exponential growth, explain the exponential growth equation, and graph it on a graphing calculator; 2) Polynomials – use Algebra Tiles to construct and solve a polynomial equation and use given data to construct a polynomial expression describing age cohorts of a population; and 3) Quadratic Functions – graph a quadratic function on the graphing calculator and use the calculator to solve it by using the Quadratic Formula.

PRACTICAL SKILLS OVERVIEW

In *Practical Skills*, students learn to identify common tools and their uses. They are introduced to the history of measuring systems, repair faulty systems, and follow directions to assemble prefabricated furniture. One important skill is to recognize situations when it would be best to call in a professional to help them solve the problem.

STUDENT OBJECT IVES

• Troubleshoot a situation and repair the system in question.

• Learn the value in following a set of instructions.

• Understand the importance of hand-tool safety, care, and use.

• Apply what they learned concerning tool identification to assemble a prefabricated item.

• Learn to correctly measure using the appropriate measuring tool.

• Explore the function of a home plumbing system.

• Assemble a secure dead bolt and learn about the importance of home security.

ACTIVITIES

Students complete three performance assessments: 1) Measurement – demonstrate the proper safety and use of the ruler and tape measure; 2) Mounting Shelf Brackets – demonstrate proper safety and use of various tools, explain how mechanical fasteners work, and produce a horizontally level shelf; and 3) Prefabricated Pull Cart – correctly and completely assemble a prefabricated item and explain how following directions can save time.

SPORTS STATISTICS OVERVIEW

In *Sports Statistics*, students explore the role of mathematics in sports statistics. Students use various data representation techniques to find trends and make predictions using actual sports statistics. Students will also collect and analyze data from their own tabletop sports and use this data to create scatter plots, frequency tables, histograms, and box-and-whisker plots. They explore many different mathematical concepts including matrices, graphing, factorials, permutations, and combinations.

STUDENT OBJECTIVES

• Write sports data in matrix format and manipulate the data by adding, subtracting, and multiplying matrices.

• Create scatterplots and determine the line of best fit to represent sports data trends.

• Create frequency tables and histograms and then use the histograms to interpret statistical information.

• Create a box-and-whisker plot by calculating the range, quartiles, median, and outliers.

• Explore and learn to apply the fundamental counting principle to sports-related issues.

• Explore factorials, permutations, and combinations and how they relate to sports statistics.

ACTIVITIES

Students complete three performance assessments: 1) Matrices – explain how to add, subtract, and perform scalar multiplication on matrices; 2) Fundamental Counting Principle – define the fundamental counting principle *and explain how to use this principle to determine the number of outcomes for a given sports situation; and 3) Permutations and*

Combinations – explain the difference between permutations and combinations and solve problems related to each.

STATISTICAL ANALYSIS OVERVIEW

While engaged in *Statistical Analysis*, students create and conduct a survey and graph their data. Students explore histograms, box-and-whisker plots, stem-and-leaf plots, bar graphs, circle graphs, and line graphs. Students use data to display statistical information. Students complete probability activities ranging from tossing two-color counters and rolling dice to generating and using Pascal’s Triangle to calculate experimental and theoretical probabilities. Students also use their knowledge of probability to create a fair game.

STUDENT OBJECT IVES

• Define terms related to statistics and probability.

• Explore uses and misuses of statistics in everyday situations.

• Complete statistical analyses in music and sports.

• Explore a variety of graphs including box-and-whisker plots and stem-and-leaf plots.

• Conduct a survey and graph data using a histogram and a box-and-whisker plot.

• Calculate experimental and theoretical probabilities.

• Conduct probability experiments using two-color counters and dice.

• Generate Pascal's Triangle and use the pattern to calculate probabilities.

• Create a fair game.

ACTIVITIES

Students complete three performance assessments: 1) Mean, Median, and Mode – define mean, median*, and* mode*; identify uses of statistics; and construct a bar graph of shooting statistics; 2) Survey Statistics – construct a valid and unbiased survey and graph the data using a stem-and-leaf plot, a histogram, and a box-and-whisker plot; and 3) Probability – define* theoretical *and* experimental probability*, define* dependent *and* independent events*, and create a histogram.*