

THE EFFECTS OF A PROJECT-BASED MATHEMATICS CURRICULUM ON MIDDLE
SCHOOL STUDENTS' INTENDED CAREER PATHS RELATED TO SCIENCE,
TECHNOLOGY, ENGINEERING AND MATHEMATICS

by

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ABSTRACT

This study is an examination of whether a project-based mathematics curriculum would influence students' intended career paths related to science, technology, engineering, and mathematics (STEM) endeavors; perceived usefulness of mathematics; and perceived competence in doing mathematics. A review of the literature revealed that there are many shortages of professionals in STEM fields. United States women and men are not pursuing STEM endeavors in great numbers and the U.S. relies heavily on international students to fill this gap. The literature revealed that the girls who do not pursue STEM endeavors in great numbers do not perceive mathematics as a useful endeavor and do not think they are competent in doing mathematics. Boys who do not pursue STEM endeavors in great numbers also do not perceive mathematics as a useful endeavor. The study involved 7th and 8th grade school students enrolled in algebra classes in a private college-preparatory school. The students in the experimental group participated in a problem-based curriculum that integrated lecture-based methods with four major projects designed to have students apply mathematics out of the context through hands-on real-life problems. This particular quasi-experimental design was a nonequivalent pre-test/post-test control group design. Statistical analyses were done using a general linear model repeated measures. The results of the statistical analyses indicated that the students in the project-based group showed a statistically significant positive change in their perceived usefulness of mathematics when compared to the control group. A t-test revealed no statistically significant differences in academic achievement. Qualitative data analysis uncovered three emergent themes. Students indicated that they saw the usefulness of mathematics more clearly; students' independence from the teacher while doing the projects was unsettling; and students enjoyed the change of pace in class. The results of the study indicated that a project-based mathematics

curriculum can help students see the usefulness of mathematics and can help students enjoy the pursuit of mathematics by this particular change of routine.

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LIST OF ACRONYMS

IT: Information Technology

NAEP: National Assessment of Educational Progress

NCTM: National Council of Teachers of Mathematics

NS&E: Natural Sciences and Engineering

NSF: National Science Foundation

PBL: Project-based Learning or Problem-based Learning

R&D: Research and Development

STEM: Science, Technology, Engineering, and Mathematics.

UCFIRB: University of Central Florida Institutional Review Board

CHAPTER 1 INTRODUCTION

The decreasing number of people pursuing science, technology, engineering, and mathematics (STEM) careers has become a cause for concern in the United States. The National Science Foundation (2002) in the document *Science and Engineering Indicators – 2002* stated that many other countries claimed that a higher population of their youth had graduated with their first college degrees by age 24 in some form of natural sciences or engineering (NS&E). Natural sciences include physics, chemistry, astronomy, earth sciences, biological sciences, mathematics, and computer sciences. The United States in 1999 had a mere six percent of its 24-year-olds holding some form of NS&E degree, while thirteen countries listed by the NSF claimed more than this. The United Kingdom, Finland, and South Korea, for instance, declared between 8% and 10%. The National Science Foundation (1986) warned that there would be serious shortages of engineers in the decades to come, and the United States is currently short of many types of engineers (Flynn, 2001).

Many international students study STEM fields in the United States. In 1999, 10 percent of the Science and Engineering bachelors' degrees, 20% of the masters' degrees, and 25 percent and greater of the doctoral degrees were earned by international students (NSF, 2002). The United States has traditionally relied on these STEM graduates to stay in the United States and become STEM professionals, and this reliance has increased in recent years (NSF, 2002). The main problem with relying on International professionals is the danger that international students, having earned their degrees in the United States, may return to their home countries to work, creating more shortages here in the United States (NSF, 2002).

Clearly, a challenge for the United States is to lure more domestic talent into STEM endeavors. Gordon Moore, cofounder of the Intel Corporation and Fairchild Semiconductor, said that “we’re in danger of exporting a lot of technological advantage because we’re not training enough people here. Education, that’s our Achilles’ heel” (Richtel, 2001, p.BU4). For instance, high school students in the United States do not take as many advanced mathematics and science courses as students from other countries (NSF, 2002). Although more than two-thirds of high school graduates in the United States go to college, both males and females have *not* traditionally pursued STEM majors in the numbers needed to satisfy all of the U.S. STEM professional needs. Undergraduate enrollment in engineering has dropped by more than 20 percent from 1983 to 1999 while the number of U.S. citizens earning doctorate degrees in NS&E has dropped by approximately 14 percent in the last twenty-five years (NSF, 2002).

Although the number of women who have STEM career aspirations has been gaining ground on the number of men with similar STEM career aspirations (Gerstein, Lichtman, & Barokas, 1988; Harmon, 1989; Katz, 1986), Smith (2000) found that the percentages of women in STEM careers is still low. In 1990 women made up 6% of the engineers, 16% of the scientists, and 4% of the computer scientists, even though women made up about 44% of the U.S. Work Force (Tobias, 1990). In fact, the United States Department of Labor (1999) found that the gender gap in newer technological occupations, such as computer scientist and computer analyst, is widening, with the number of women lagging seriously behind. Women, it seems, continue to flock to careers typically dominated by women (National Center for Education Statistics, 2000), particularly careers in health related fields, education, social science, and behavioral sciences (Larsen, 2001). The gap between boys’ and girls’ intentions to pursue STEM careers is measurable as early as the eighth grade (National Center for Education Statistics, 1997).

Children also begin to eliminate careers as early as age 6 because they are the wrong “sextype” (Stitt-Gohdes, 1997).

Men in the United States are not pursuing STEM careers in great numbers either. Although 82% of the Engineering degrees went to men in 1995-1996 (Digest of Educational Statistics, 1998), many of these degrees went to students from other countries. Approximately 30 percent of all students enrolled in graduate schools of science and engineering are from countries other than the United States, and about 60 percent of the engineering doctorates were earned by non-U.S. citizens (Nadis, 1997). Eighty-three percent of the junior faculty in electrical engineering are not U.S. citizens (Nadis, 1997). United States’ businesses that rely on STEM college graduates have consistently relied on recruiting a substantial number of employees from the pool of internationally-born college graduates (Armstrong, 2003).

Both the Information Technology Association of America Study and the Stanford Computer Industry Project Study (cited in Bellinger, 1997) determined that there were shortages of software programmers and information-technology (IT) personnel. The shortages have proven to be a significant obstacle in the growth of many corporations since many of these positions remained unfulfilled (Bellinger, 1997). Tobias (1998) reported that with an average need for over 135,000 IT specialists per year, the average yearly supply of 35,000 college IT graduates was clearly not sufficient. Over 75% of the IT jobs would not be filled. Bellinger (1997) suggested that continued immigration of talent from overseas will provide solutions to these STEM shortages.

The terrorist attacks on the United States on September 11, 2001 have certainly led to tighter scrutiny of all international students entering the United States for schooling. With a potential decline in the number of international students available for STEM college degrees, the

men and women of the United States must be enlisted to bridge the gap. Armstrong (2003) questioned whether it will be possible to compensate with current domestic recruiting methods.

Statement of the Problem

United States citizens are not pursuing STEM endeavors in the numbers necessary to ensure that the United States remains economically competitive in STEM industries throughout the world (NSF, 2002). STEM-type industries are important to a country's growth since "they produce a large share of innovations, including new products, processes and services that help gain market share, create entirely new markets, or lead to more productive use of resources" (NSF, 2002, p. O-8).

Women, both domestic and international, remain underrepresented in STEM college majors and careers. Even though more women are entering college than ever before, women still remain underrepresented in mathematics, physical sciences, and engineering (Kramer, 2001). Men from the United States are also underrepresented in STEM college majors and careers. Parelius (1991) found that men are more likely to persist in STEM majors than women with similar ability levels, even when both begin college with the intention of pursuing STEM majors. According to the *Digest of Educational Statistics* (1998) in a measurement of bachelor's, master's, and doctoral degrees conferred by institutions of higher education in 1995-1996, only 18% of the engineering degrees went to women.

In 1999, the enrollment in science, computer science and engineering graduate schools increased. However, the enrollments increased due to an influx of approximately 8,000 international students, while the number of U.S. students *decreased* by a little more than 1,000 (Coy & Whalen, 2001). In 1994, of the 9,269 doctoral degrees earned in engineering, chemistry,

and physics, approximately 45% of the recipients were United States citizens (7% women, 38% men) while 56% of the recipients were international students (4% women, 52% men) (Santiago & Einarson, 1996).

The purpose of this research study was to determine if a project-based mathematics curriculum would influence middle school students' intentions to pursue career paths related to science, technology, engineering, and mathematics.

Girls' Non-participation in STEM Pursuits

Why most girls shy away from STEM endeavors has been well studied (NSF, 2002; Ethington, 2001; Bohlin, 1994; Lapan & Jingeleski, 1992; McDonald & Jessell, 1992; Dick & Rallis, 1991; Fennema, 1990; Leder, 1990; Meyer & Koehler, 1990; Keith, 1988; Rotberg, Brown, & Ware, 1987; Armstrong, 1985; Zuckerman, 1985; Armstrong & Price, 1982; Hackett & Betz, 1981; Lantz & Smith, 1981; Pedro, Wooleat, Fennema & Becker, 1981; Fennema & Sherman, 1978; Sherman & Fennema, 1977). The differences between girls' and boys' achievement on the National Assessment of Educational Progress (NAEP) long-term trend assessment levels showed slight but statistically insignificant gaps favoring boys in mathematics and the sciences in 1999 (NSF, 2002). When course taking was controlled, Fennema (1990) found that there are few sex-related differences in achievement. Dick and Rallis (1991) studied over 2,000 high school seniors and also found that even female students with "exceptional high school mathematics and science preparation" (p. 291) have very different career plans than male students with the same exceptional preparation. Turner and Bowen (1999) found that girls with high Scholastic Achievement Test (SAT) scores were not likely to choose STEM majors in

college. In fact, Grandy (1990) found that only 15% of the girls scoring above the 90th percentile on the SAT chose a STEM college major.

A question naturally arises. If girls' ability is not in question, then what other factors are involved in the disproportion? There are several factors that have emerged in relation to gender differences in STEM participation and two of these factors shall be considered in this study.

Perceived usefulness of STEM courses (Leder, 1990; Meyer & Koehler, 1990; Armstrong, 1985; Armstrong & Price, 1982; Lantz & Smith, 1981; Pedro, Wooleat, Fennema, & Becker, 1981) and perceived competence in STEM courses (Ethington, 2001; Bohlin, 1994; Lapan & Jingeleski, 1992; McDonald & Jessell, 1992; Leder, 1990; Meyer & Koehler, 1990; Keith, 1988; Rotberg, Brown, & Ware, 1987; Zuckerman, 1985; Hackett & Betz, 1981; Lantz & Smith, 1981; Fennema & Sherman, 1978; Sherman & Fennema, 1977) are important factors contributing to girls' decisions to pursue or not pursue STEM endeavors (See Figure 1). Both of these factors contribute to and influence female students' decisions not to pursue higher-level STEM courses in high school and college or STEM careers beyond college.

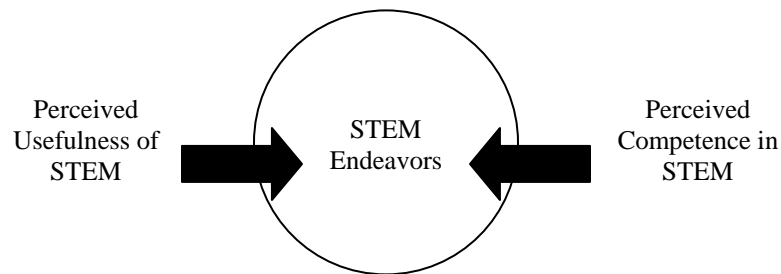


Figure 1: Factors Contributing to Girls' Decisions to Pursue STEM Endeavors

Boys' Non-participation in STEM Pursuits

Currently there are shortages and predicted shortages in many STEM fields (Bellinger, 1997). Clearly the issue of female's non-participation in STEM endeavors contributes to this shortage, but the lack of male participation also contributes to the shortages. The factors contributing to males' non-participation in STEM endeavors has not been very well researched, but there seem to be three factors contributing to boys' decisions to pursue or not pursue STEM endeavors (See Figure 2). Lack of perceived usefulness of STEM endeavors (Armstrong, 1985; Armstrong & Price, 1982), perceived "nerd" image (Eisenhart, Finkel, Behm, Lawrence, & Tonso 1998), and perceived blue-collar status of STEM careers (McIlwee & Robinson, 1992) are the factors contributing to males' non-participation in STEM endeavors.

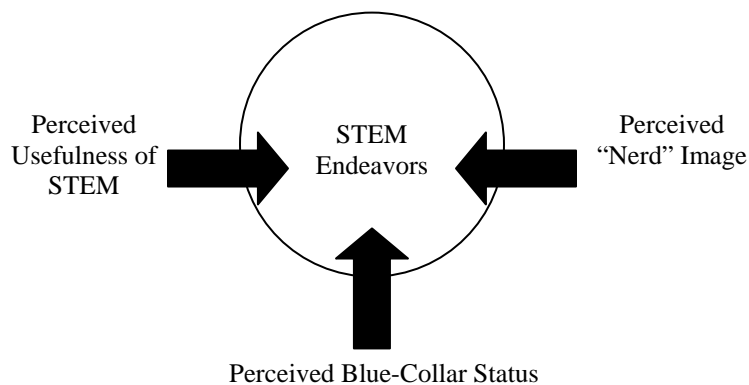


Figure 2: Factors Contributing to Boys' Decisions to Pursue STEM Endeavors

The Purpose of the Study

The purpose of this study was to investigate whether a project-based mathematics curriculum helped increase middle school students' intentions to pursue mathematics and other STEM endeavors. A project-based mathematics curriculum proposed to help all students, both

boys and girls, increase their perception of the usefulness of mathematics, increase their perception of their own competence in mathematics, and increase their interest in future STEM pursuits.

Research Questions

The research in this study determined whether the students in the experimental group evidenced an increased positive change over time in attitudes regarding any of the following three constructs: plans for participation in future STEM endeavors, perceived usefulness, and perceived competence. The following research questions were explored.

1. Did the students in the experimental group show a statistically significant positive change in attitudes regarding plans for future participation in STEM endeavors when compared to the change in attitudes of the control group?
2. Did the students in the experimental group show a statistically significant positive change in attitudes regarding perceived usefulness of mathematics when compared to the change in attitudes of the control group?
3. Did the students in the experimental group show a statistically significant positive change in attitudes regarding perceived competence in mathematics when compared to the change in attitudes of the control group?
4. Did the students in the experimental group and the students in the control group have any significant differences in their academic achievement as measured by their respective semester examinations?

Rationale

A search of the literature revealed that there are shortages in professional STEM participation. Both women's and men's domestic participation in STEM endeavors is reaching critically low levels, while the percentage of foreign-born professionals is steadily increasing (NSF, 2002).

Women's participation in STEM endeavors as evidenced by course-taking patterns, college major selections, and career choices are significantly lower than men's. Although girls' ability levels in STEM courses are comparable to boys', girls' participation in STEM courses in high school and college is also proportionally lower than the boys', although the gap has narrowed in recent years (NSF, 2002). Although women's participation in STEM careers has increased over the years, the proportion of women is nowhere near that of men.

The literature also revealed that although men make up the majority of those pursuing STEM fields, the proportion of men from the United States has been declining dramatically in recent years when compared to the number of men from other countries (NSF, 2002).

Project-based Curriculum

A project-based mathematics curriculum attempts to make mathematics curriculum more relevant for students (Henry, 1994) by incorporating projects that provide hands-on experiences and real-life problem-solving situations. Incorporating hands-on experiences and real-life applications in the form of project-based learning (PBL) has been shown to have a positive effect on students' enthusiasm for learning (Milner-Bolotin, 2001; Hmelo, 1998). Henry (1994) suggested that it is this relevance that motivates students to participate actively and helps keep students traditionally alienated from STEM endeavors interested in these subjects.

Females and a Project-based Curriculum

A study by the Society of Women Engineers found that being good in mathematics and sciences is the main reason that women became engineers (Ellis & Eng, 1991). This was not so for the men in the study. McIlwee and Robinson (1989) surveyed and interviewed women and

men who are professional engineers and found that the women entered the field through very different paths than men. They found that for the most part, women entered engineering because they had strong mathematics skills. Ninety percent of the professional women engineers in their survey indicated that they did not have a clear idea what engineers did nor did they have much experience tinkering with mechanical devices. Men, on the other hand, mostly entered engineering because they had a strong orientation towards tinkering and working with mechanical devices.

Bohlin (1994) surveyed 421 high school students from six randomly selected large public high schools in a large midwestern U.S. city who were currently enrolled in Algebra II courses. She found that the girls in the study were significantly less involved in technical activities and had less interest in technical careers than did the boys. Many tended not to see mathematics as a particularly useful endeavor and subsequently opted out of further mathematics study.

The differences McIlwee and Robinson (1992) found in the women's preparation for engineering work placed these women at a disadvantage once they entered the professional arena. A lack of experience or comfort with hands-on tasks seemed to become internalized as incompetence, but perhaps the problem was merely a general lack of experience with hands-on applications (Seymour & Hewitt, 1997). Kimball (1989) suggested that girls tend to measure lower on skills of problem-solving *not* because they do not have the ability for problem-solving, but because they have not been socialized to experience mathematics- and science-related activities that would involve solving problems and consequently do not perceive themselves competent at solving problems.

Males and a Project-based Curriculum

McIlwee and Robinson (1992) also discovered in their study of professional engineers that men tend to be more aware of engineering because they are socialized to be tinkerers. The engineers who proclaimed themselves tinkerers said that “as boys they were in love with machinery or electronic...Cars, computers, airplanes, stereos, radios – anything that moved or was plugged into an outlet - fascinated them...They were good students but with grease under their finger nails” (pp. 25-26).

Although males seem to be more aware of STEM careers and are consequently more apt to pursue such careers, there is an image that engineers, scientists, and computer scientists are “nerds” or “geeks,” which are hardly attractive types of people to desire to emulate (Eisenhart, Finkel, Behm, Lawrence, & Tonso 1998). The stereotype conjures images of a nerd “hunched over a slide rule or...computer keyboard...devoid of social skills, or of concern for his appearance” (McIlwee & Robinson, 1992, p.17). This is hardly an appealing career goal for either males or females.

STEM careers have also been strongly identified with blue-collar occupations and as a way for men to rise out of poverty in order to improve their socio-economic status and change their class association (McIlwee & Robinson, 1992). On the flip side, middle-class and affluent men and women may feel that blue-collar work is beneath them and would not consider STEM careers, even though they would be quite good at them.

In their surveys of high school students, Armstrong (1985) and Armstrong & Price (1982) discovered that lack of perceived usefulness of mathematics also influenced males participation in future STEM endeavors as well as females. Clearly, if students do not perceive an enterprise to be useful they will not pursue such a task (Meyer & Koehler, 1990).

Mathematics' Emphasis on Critical Thinking and Problem Solving

The National Council of Teachers of Mathematics (2000) in their document *Principles and Standards for School Mathematics* called for an emphasis on critical thinking and problem solving. The NCTM suggested, “the curriculum should offer experiences that allow students to see that mathematics has powerful uses in modeling and predicting real-world phenomena. The curriculum also should emphasize the mathematics processes and skills that support the quantitative literacy of students” (NCTM, 2000, pp.15-16). A project-based curriculum allows students to apply their mathematical knowledge and learn more mathematics in context. Students are forced to use higher-order cognitive skills such as organizing, synthesizing, analyzing, and evaluating since the projects, by design, force students to “think things out for themselves, so stimulating cognitive skills” (Henry, 1994, p. 49).

Hmelo (1998) found that medical students learning through project-based learning (PBL) were more apt to use actual science concepts when making arguments than were the non-PBL students. She stated that project-based learning integrates basic subject-matter knowledge with concrete experiences and facilitates reasoning skills. This facilitation in a mathematics classroom will help students make connections between mathematics skills and applications, thus enhancing students' mathematical literacy.

The NCTM (2000) is critical of purely lecture-based methods of mathematics teaching. “Unfortunately, learning mathematics *without* understanding has long been a common outcome of school mathematics instruction” (p. 19). Tobias (1990) found that many of the students in her study did not get interested in science since most of the problems had “all been solved before [and] rarely were they a source of new insight” (p. 42). Wagner (2002) likened students learning mathematics through lecture-based instruction to a bus full of tourists. He compared the students

to tourists who have a mathematics teacher as their tour guide. The tour guide often “hurries students from one ‘must-see’ curriculum outcome to another, uninterested in the connecting places between these sites and unconcerned with the greater whole to which they all belong.... They [the teachers] may be unaware of the shallow experience of mathematics they provide for students” (p. 51). A project-based curriculum seeks to help students make connections and understand the greater whole of mathematics.

Projects in a project-based curriculum are intended to position the students at the center of the pursuit of mathematical understanding. Students become, out of necessity, mathematical thinkers. In a project-based mathematics learning environment students are asked to evaluate a situation, collect data, come up with a potential solution, test the solution, rethink the solution if necessary, and finalize the results. The NCTM (2000) states, “Students learn more and learn better when they can take control of their learning by defining their goals and monitoring their progress. When challenged with appropriately chosen tasks, students become confident in their ability to tackle difficult problems, eager to figure things out on their own, flexible in exploring mathematical ideas and trying alternative solution paths, and willing to persevere” (p. 20). It is this sense of eagerness and exploration that one hopes will instill a sense of attachment to mathematical thinking and persistence in the field.

Significance of the Study

Goodwin and Nacht (1983) warned that many graduate schools in STEM fields such as engineering have had a strong dependence on foreign students and “without foreign students they (engineering graduate schools) would have had to close down their graduate programs in the

short run and their whole operation ultimately” (pp.12-13). Solomon and Young (1987) point out that international students “often fill empty seats not sought by Americans” (p.93).

Sells (1973) warned that mathematics acts as a “critical filter” keeping women out of STEM fields of employment. Both Fennema (1990) and Leder (1990) voiced concern about girls who do not persist in STEM courses in high school and beyond. They warned that options become closed to women who opt out since many mathematics courses are required as prerequisites for many STEM areas of study (Leder, 1990; Sells, 1973). The ramifications of this early decision could have serious financial repercussions for these women who are capable, but choose different paths. Fennema (1990) also noted “the entire field of mathematics might be enriched if more young females were given the opportunity to grow into mathematical scholars” (p.2).

Turner and Bowen (1999) reported that science policy analysts are concerned about such a severe underrepresentation of women and minorities in STEM careers since this implies the loss of potential talent. Faulkner (2000) pointed out that there is a need for female engineers and scientists. She said, “Few would argue with the notion that women designers should be more likely to ‘see’ the needs of particular female users (e.g., for wider gangways on buses, to allow for women with young children, or airbags that are not lethal to short women)” (p. 99). Clearly the lack of different voices, both female voices and underrepresented male voices, has consequences for all since these voices can make valid contributions to STEM fields.

Definitions of Terms

NS&E: The acronym stands for Natural Sciences and Engineering. The natural sciences include physics, chemistry, astronomy, earth sciences, biological sciences, mathematics, and computer sciences.

STEM: The acronym stands for science, technology, engineering, and mathematics (NSF, 2003) and is used as an adjective to describe something related to science, technology, engineering, and mathematics.

STEM Participation: Participation by taking upper level science, technology, and mathematics courses in high school or college; majoring in science, technology, engineering, and mathematics as an undergraduate; or pursuing careers in science, technology, engineering, and mathematics.

Project: An in-depth study in which students are engaged in a purposeful activity.

Project-based Learning (PBL), Problem-based Learning, Project-based Instruction, Project-based Curriculum: Consist of a learning environment in which projects or problems are used in addition to lecture-based instruction to help students make connections between content and application of content.

Overview of the Dissertation

Chapter 1 discusses the factors influencing students' participation or non-participation in STEM endeavors and offers PBL as one possible solution that will keep students interested in STEM endeavors in high school, college, and beyond. PBL is a method of instruction that engages the student in application of content through original inquiry, exploration, and problem solving.

Chapter 2 contains a review of the theoretical and empirical literature that guided the current research project.

Chapter 3 presents the research questions and outlines the methodology of the study. The methodology explains the research participants, the treatment, the measuring instruments (pre- and post-questionnaires as well as semester algebra exams), and the data analysis of the study.

Chapter 4 examines the quantitative results of the questionnaires, semester algebra exams, and the qualitative data collected from student interviews, reflections, presentations, and write-ups, as well as teacher interviews. The results were examined as to their significance as they relate to the various research questions proposed.

Chapter 5, the final chapter, discusses and interprets the results in terms of the research questions proposed. Suggestions for further research are also presented.

CHAPTER 2 REVIEW OF LITERATURE

The primary purpose of this research was to investigate whether a project-based mathematics curriculum would influence middle school students' intentions to pursue some form of science, technology, engineering, or mathematics career. This research study also sought to determine if a project-based mathematics curriculum would influence middle school students' perceptions of the usefulness of mathematics and their perceptions of their own competence in doing mathematics.

NCTM's Call for Quantitative Literacy

The NCTM (2000) called for an emphasis on critical thinking and problem solving within mathematics education. The NCTM counseled that mathematics education should promote mathematically literate students who are capable of solving real-world problems. This notion of quantitative literacy is certainly not a new one. Many renowned educators, such as Kilpatrick (1918, 1926) and Dewey (1900, 1916) emphasized the methods and means for making students' school experiences relevant to their lives.

A project-based curriculum is a method that promises to immerse students into real mathematics. As students work through projects they make connections between the mathematics they learn in school and real-world problems. As students take on the responsibility for planning, executing, and revising their projects, it is hoped that they will come to understand the ways and means for making these connections. And it is through these connections that students will come to value mathematics and its pursuit. As students see the usefulness of mathematics and succeed in applying mathematics, they will make strides towards quantitative literacy.

Factors Contributing to Students' Non-Participation in STEM Pursuits

The primary research goal in this dissertation was to find a method and means for attracting young people to and keeping them in STEM endeavors. These STEM endeavors include taking more science, technology, and mathematics courses in high school and college; majoring in science, technology, engineering, and mathematics in college; or pursuing careers in science, technology, engineering, and mathematics. If the goal is to hook young people into STEM endeavors, then a further look into the oft-studied reasons students do *not* pursue STEM endeavors is in order.

One of the factors contributing to students' decisions to pursue or not pursue STEM endeavors is the perceived usefulness of STEM courses. Another often-studied factor, that is more of a factor for girls than boys, is students' perceived competence in STEM courses. Both of these factors contribute to and influence female and male students' decisions to pursue higher-level STEM courses in high school, STEM courses in college, STEM college majors, and STEM careers beyond college.

Perceived Usefulness of STEM endeavors

Students who do not see STEM pursuits as useful endeavors often opt out of non-required and higher-level STEM courses. Naturally, students will not take these courses if they do not see where such courses of study will be useful to them (Meyer & Koehler, 1990). Armstrong (1985) surveyed over 1,400 eighth-grade students and over 1700 twelfth-grade students from Duluth, Minnesota and Columbus, Georgia. The survey attempted to discern what variables affected students' decisions to pursue or not pursue upper level mathematics courses. Although she was primarily interested in females' decisions to participate in future mathematics courses, she

reported results for both males and females. Both the younger and the older students, males and females alike, reported that usefulness of mathematics was the number one factor affecting their decisions to take more mathematics.

Armstrong and Price (1982), in a national survey of high school seniors, found that both girls and boys rated perceived usefulness of mathematics as the most important factor contributing to their continued participation in mathematics courses and other STEM endeavors. Pedro, Wooleat, Fennema, and Becker (1981) found similar results with their study involving over 1,200 Geometry students from ten different high schools.

Lantz and Smith (1981) studied factors that influenced whether high school students would enroll in non-required mathematics courses. The students in the sample were enrolled in their last required mathematics class. The researchers found several factors that significantly influenced students' decisions to pursue non-required mathematics courses. One of the leading factors influencing both female and male students' decisions to pursue more mathematics was the subjective value, or usefulness, that students placed on taking more mathematics.

Perceived Competence in STEM Courses

Perceived competence is not the actual ability level as measured by a grade in a course or a score on a standardized test, but the students' *perceived* ability to learn, understand, and master material. At both the middle school and high school levels, females reported lower levels of confidence in their ability to learn mathematics than did males (Fennema, 1990; Meyer & Koehler, 1990; Fennema & Sherman, 1978; Sherman & Fennema, 1977). Girls, it seems, tend to underestimate their own abilities; that tendency, in turn, undermines their self-confidence (Chan, 2000).

According to researchers, girls have lower confidence levels about their abilities even when they achieve at the same level as boys (Leder 1988; Eccles, 1983; Lantz & Smith, 1981; Fennema & Sherman, 1978; Sherman & Fennema, 1977). Meyer & Koehler (1990) found this effect at both the middle school and high school levels. Bohlin (1994), in her study that surveyed Algebra II students, found that even though the girls' grades in mathematics courses were on the whole as high or higher than the boys, these girls tended to have less confidence in their abilities to do well on mathematical tasks involving applications and problem solving. Vetter (1996) suggested that females, although tending to have higher grades than their male counterparts, do not persist in STEM endeavors in order to avoid embarrassment about possibly performing below expectations.

Several researchers have found that confidence in STEM courses is a good predictor as to whether or not a student will continue to participate in STEM endeavors by taking higher-level courses in high school, pursuing STEM college majors, and pursuing STEM careers (Meyer & Koehler, 1990; Eccles, 1983; Armstrong & Price, 1982; Lantz and Smith, 1981). In their survey research with high school seniors, Armstrong and Price (1982) found that girls ranked confidence as their number two reason (behind usefulness) influencing their non-pursuit of STEM endeavors. Boys ranked confidence as their third highest overall reason for not pursuing STEM endeavors (behind usefulness and dislike of mathematics). Armstrong and Price found a high correlation between the girls' and the boys' rankings and conjectured that "many of the variables may be operating in the same way for males and females" (p.104). In other words, similar factors may be at work influencing girls and boys and their pursuit or non-pursuit of STEM endeavors.

Eccles (1983) conducted a longitudinal study and found that perceived competence in mathematics was a better predictor of future mathematics course taking than other traditional measures such as achievement. Lantz and Smith (1981) also found in their survey of high school students that although perceived usefulness was the leading factor contributing to students' continued participation in non-required mathematics, confidence in one's abilities was also important. They found that significant numbers of students who intended to take further non-required mathematics courses but did not take these courses were generally those who had less confidence in their abilities to do well in mathematics.

The American Association of University Women (1992) in their influential document *How Schools Shortchange Girls* reported that girls seem to develop a learned helplessness and subsequently do not persevere in their studies of mathematics and science. Dweck (1986) theorized that this learned helplessness stems from girls' socialization to believe that intelligence is innate and is an entity that a person has or does not have. Boys, on the other hand, are more likely to believe that intelligence is incremental and can be increased by hard work. Girls, holding this entity theory of education, are more likely to attribute a lack of understanding to a lack of intelligence and may "opt for easier programs of study, avoiding advanced math and science because these feel too risky" (Dweck, 1999, p.124). Boys tend to attribute a lack of understanding either to a lack of effort or to external factors, but not typically to a lack of intelligence. Consequently, boys will persist more when the "going gets tough."

Pedro, Wooleat, Fennema, and Becker (1981) also found that boys tended to attribute success to ability while females attributed success to effort, but failure to lack of ability. They found that both males and females who attributed success to ability were more apt to plan to take more mathematics.

Ethington (2001) studied girls who intended to pursue STEM majors. The students in the study were proficient in mathematics, and yet even these students did not tend to attribute their success to ability. In fact, they were more apt to attribute their success to luck. The girls in this study felt that their intelligence was innate and they could not do much to improve. Heyman, Martyna, and Bhatia (2002) surveyed over 200 male and female engineering students at the University of California, San Diego and found that the females were much more likely to categorize aptitude in engineering as a fixed ability. These female engineering students were much more willing than their male counterparts to drop classes that seemed too difficult. This further illustrates the notion that females tend to consider intelligence an inborn quality and may consider obstacles such as difficult courses insurmountable.

As educators learn more about the nature of intelligence and learning, inroads are made into the best ways for students to learn. Constructivism is one philosophy of learning (Phillips & Early, 2000). The student is at the core of a constructivist philosophy. Students, as they learn, make individual and unique connections. These connections are said to be “constructed” and in this construction “many students will solidify conceptions about themselves as learners of mathematics – about their competence, their attitude, and their interest and motivation. These conceptions will influence how they approach the study of mathematics in later years, which will in turn influence their life opportunities” (NCTM, 2000, p. 211).

Constructivism

The National Council of Teachers of Mathematics (NCTM, 2000) advocates a constructivist approach to mathematics instruction. Constructivism refers to the learning philosophy that learners construct knowledge and meaning for themselves. The NCTM (2000)

stated “Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge” (p. 11). Learning, therefore, is not so much the acquisition of knowledge “out there” but a creation of meaning by each individual.

The National Research Council (1989) in their report *Everybody Counts: A Report to the Nation of the Future of Mathematics Education* also espoused a constructivist view of learning and stated that “the process of ‘doing’ mathematics is far more than just calculation or deduction; it involves observation of patterns, testing of conjectures, and estimation of results” (p. 31). The report criticized lecture-based methods of instruction, stating “one can hardly blame students for not becoming interested in mathematics if they rarely see evidence of its full power and richness” (p. 43). Too often “mathematics appears to be a hostile place in which only experts can dwell” (Wagner, 2002, p. 59). Constructivism suggests that students need opportunities to develop their own understandings of the subject matter by digging into the process themselves (Eisenhart, Finkel, Behm, Lawrence, & Tonso, 1998). Project-based instruction is grounded in this basic tenet of constructivism. The project method of applying mathematics to real-world problems is part of this process of “doing” mathematics.

Project-based Curriculum

Katz and Chard (1989) defined the term “project” as “an in-depth study of a particular topic” (p. 2). Kilpatrick (1918) defined a project as “a wholehearted purposeful activity” (p. 1). Project-based learning, project-based instruction, and project-based curriculum are terms that, in this dissertation, comprise a learning environment in which projects are used in addition to lecture-based instruction to help students make connections between content and application of content.

The primary aim of a project-based curriculum is to introduce students to real problems that may have one or more possible solutions or may be ill defined and ambiguous. Project-based instruction, in addition to helping students apply content, is designed to help students develop investigative and hands-on skills. A project-based curriculum requires students to communicate and work cooperatively with classmates (Kaufman & Mann, 2001). The main idea of a project-based learning environment is for students to pull from their store of mathematical content knowledge or acquire new mathematical knowledge in order to solve problems or make sense of a situation.

Medical Schools and Project-based Learning

Medical schools have been quick to take on problem-based learning as a means for teaching medical students. Several researchers (Albanese & Mitchell, 1993; Vernon & Blake, 1993), after analyzing studies on project-based learning in medical schools, concluded that learning from project-based instruction is superior to other forms of instruction with respect to students' "approach to study (being more likely to study for understanding rather than for short-term recall); long-term retention of knowledge;...motivation for learning; [and] perceptions of their education (being more positive)" (Schwartz, Mennin, & Webb, 2001, p.4).

Albanese and Mitchell (1993) conducted a meta-analysis of literature concerning problem-based learning in medical schools from 1972 to 1992. Their research suggested that students found PBL to be more "nurturing and enjoyable" (p.52). They found that students learning under PBL scored either as well as or better on clinical hands-on examinations than students learning under lecture-based conditions. However, they also found that in some of the studies, PBL students did not do as well on examinations of their knowledge base. This indicated

that some students learning under PBL were learning less content. However, it seems that the content they were learning was learned with deeper understanding and better applicability than their lecture-based counterparts.

Vernon and Blake (1993) also conducted a meta-analysis of studies involving medical schools using problem-based learning. The researchers evaluated 35 research studies from 19 different institutions covering the years 1970 to 1992. They compared problem-based approaches with traditional lecture-based approaches in medical school education. They found that, for the most part, students studying under the project-based methods had significantly higher positive attitudes about their medical educations. The PBL students also showed much greater ability in their practical hands-on evaluations. And, although the students in both groups showed no significant differences on their tests of academic knowledge given by the medical schools, the lecture-based students did score significantly better on the National Board of Medical Examiners examination (Part I).

The research involving project-based learning in medical schools indicates that students tend to become more involved with and have a better attitude towards their studies (Schwartz, Mennin, & Webb, 2001; Albanese & Mitchell, 1993; Vernon & Blake, 1993). However, one major concern that surfaced in this research is the difference in student mastery of content. Naturally, content mastery is an important issue for a curriculum based on projects. Conversely, students in the project-based curriculum seemed to be able to apply their knowledge more efficiently in hands-on tasks. It is this connection between content mastery and hands-on applications that is at the heart of project-based learning.

Connections between Mathematics and Real-world Problems

A project-based approach is an attempt to take away the negative association of lecture-based instruction and replace it with cooperative ventures among students and teachers. A project-based curriculum is a means for providing students with more hands-on experience. This approach to studying mathematics attempts to inspire positive viewpoints towards mathematics and may have an influence on students' sense of usefulness and competence in its pursuit (Armstrong & Price, 1982). Problem-based curricula that emphasize cooperation and problem solving may help students become more interested in learning for mastery and learning about "how things work" (Heyman, Martyna, & Bhatia, 2002). Kimball (1989) pointed out that students with lesser outside experience with mathematics and science, usually girls, do not feel confident pursuing future mathematics classes. Learning for understanding as opposed to learning for a grade is much more likely to motivate students to persist in their STEM studies (Heyman, Martyna, & Bhatia, 2002; Eccles, 1987).

As students succeed in tackling problems, both boys and girls make connections to mathematics and its usefulness in solving real-world problems. As they find success they may experience greater self-esteem and experience a higher sense of perceived competence. As the students see the value of the projects and their applications to science, technology, engineering, and mathematics disciplines, they may begin to see the usefulness of mathematics and the pursuit of these disciplines. Students will become more familiar with the jobs that real-life engineers and scientists do and come to understand that the mathematics they have been learning in school has useful applications for solving problems. As students work through projects, they may discover that the mathematics and science they accepted as a given was once someone else's struggle, exploration, and discovery.

Basic Principles of a Project-based Curriculum

Project-based instruction allows students to actively participate in their own learning (Chard, 2000). Through investigative work students experience the types of problem solving that engineers and scientists do on the job. In other words, a project-based mathematics curriculum allows students to actually *do* engineering and science. The key to a project-based curriculum is to allow students to find their own solutions to the problem at hand instead of simply applying the current mathematical procedure being taught in class. Schoenfeld (1985) made this distinction between a problem and an exercise: “If one has ready access to a solution schema for a mathematical task, that task is an exercise and not a problem” (p. 74). A problem, he says, is one for which students do not have an immediate solution and must search their internal databanks for potential solutions.

Active Learning

Students in a project-based curriculum learn actively. Students analyze a problem situation, collect data, gather information, form hypotheses, test these hypotheses, and ultimately zero in on a result. In this manner students come to understand where the mathematical content they have learned might be applied. This process allows students to begin to answer for themselves the question many of them ask, “When are we ever gonna have to use this?” (Saunders, 1990).

Group work is an important aspect of project-based learning. Students within groups must work together towards a common goal. In working together they must explain their thoughts and ideas so that others will understand them, and they must be ready to defend their

ideas. It is in this manner that students internalize the material, make it their own, and come to a deeper understanding of the tasks in which they are engaged (Stevens, Slavin, & Farnish, 1991).

School is Life

John Dewey (1900) said “there is very little place in the traditional schoolroom for the child to work” (p. 32). The traditional layout of desks in symmetric rows, he claimed, was meant for listening and reading only. The “work” Dewey envisioned would be the kind of work “in which the child may construct, create, and actively inquire” (Dewey, 1900, p. 32). A project-based curriculum allows students the freedom to do their own “work” as they investigate problems.

Dewey was concerned that school subject matter often seemed to bear little resemblance to life situations. He wrote, “The ties are so loosened that it often appears as if there were none; as if subject matter existed simply as knowledge on its own independent behalf, as if study were the mere act of mastering it for its own sake” (1916, p. 181). Dewey envisioned a learning environment in which “activity on the part of the children preceded the giving of information on the part of the teacher [and] the children had some motive for demanding the information” (Dewey, 1900, p. 32).

Prominent educator William Heard Kilpatrick agreed with Dewey on this issue and championed the project method. He felt that the project-method curriculum would help students become more involved and committed to learning. He said, “We learn better – certainly as a rule – when we face a situation calling for the use of the thing to be learned” (1926, p. 357).

Kilpatrick (1918) insisted that the purpose of education was for students to experience life itself. Education was *not* merely a means of preparation for life after school. He envisioned the

traditional school methods of drill-and-practice and recitation to be a form of coercion. He said, “Heretofore a regime of coercion has only too often reduced our schools to aimless dawdling and our pupils to selfish individualists” (1918, p. 8). The project method would be the “best guarantee of the utilization of the child’s native capacities now too frequently wasted” (Kilpatrick, 1918, p. 8). He envisioned the project method as a guide for the curriculum in which the students would have “a series of experiences in which by guided induction the child makes his own formulations. Then they are his [sic] to use” (Kilpatrick, 1926, p. 310).

Lave and Wenger (1991) wrote extensively about situated learning. They described situated learning as learning that takes place in real-world and authentic situations. Apprenticeships are an example of situated learning. Lave and Wenger suggested that current school learning is indeed, as Kilpatrick suggested 65 years earlier, a form of coercion in which students are coerced into doing schoolwork to earn grades. Few, they said, study because they are really interested in the subject. Real-world, situated learning, such as those found in apprenticeships, provide motivation for students because the students believe the work they are doing may have real benefit for them in the future (Eisenhart, Finkel, Behm, Lawrence, & Tonso, 1998).

Teachers in a Project-based Curriculum

The traditional role of the teacher changes in a project-based environment. Since the students have more freedom exploring their project and thinking on their own, the teacher takes on more of a guiding role. The teacher becomes the *guide at the side* instead of the *sage on the stage*. The NCTM (2000) asserts, “Worthwhile tasks alone are not sufficient for effective teaching. Teachers must also decide what aspects of a task to highlight, how to organize and

orchestrate the work of the students, what questions to ask to challenge those with varied levels of expertise, and how to support students without taking over the process of thinking for them and thus eliminating the challenge” (p. 18). In a project-based environment, teachers must help students stay engaged with the project without doing the work for them. Teachers guide students by encouraging them when they lose confidence, providing suggestions when they hit road blocks in their thinking, answering their questions, and directing students to promising sources of information (Katz & Chard, 1989). Teachers offer general advice to their students, and allow the students to come up with the specifics. Students must “be encouraged to rely on the database of their own personal experience” (Katz & Chard, 1989, p. 121).

Davis (1997) envisioned an environment in which students and teachers engage in “jointly exploring a mathematical issue rather than attempting to master already formulated bits of knowledge” (p. 368). Part of the teachers’ role in a project-based curriculum is to ensure that the projects selected are worthy of study, are feasible, and will bring out appropriate curriculum content. Katz and Chard (1989) assert that one of the primary goals of project work is to help students acquire new knowledge. Projects selected should be designed to capture students’ interests, spark their curiosities, and allow them to make connections between mathematics and real-world problem solving.

Concerns about Project-based Instruction

Teacher as the Guide on the Side

Non-traditional teaching methods such as project-based learning require some adjustment on the part of the teachers involved. The teacher in a project-based learning environment acts as the *guide at the side* instead of the *sage on the stage*. Scarano (2000) found that teachers

attempting to teach through non-traditional means struggled with the “notion that disseminating information was the central purpose of teaching” (p. 168). Teachers must be ready to guide students through their interactions with the material. As Dewey (1916) said, teachers “must have subject matter at [their] fingers’ ends” (p. 183) or at least be able to point students towards helpful sources.

PBL as the Entire Curricular Approach

Bagley (1921) had misgivings about an entire curriculum completely dominated by the project method. He felt that there was a place for lecture-based means of instruction in partnership with project-based learning. He argued that the project method on one hand gives students great freedom over the curriculum learned but on the other hand “there can well be some measure of controlled and directed activity to take care of the types of learning which our adult judgment deems essential and which the child may not happen to hit upon independently” (p. 4). Mifflin and Price (2001) suggested, “the best of conventional teaching, rather than being antithetical to the development of self-direction through PBL, is actually a necessity” (p. 101). Guidance and strategic intervention are essential aspects of project-based instruction, and this guidance and intervention often come in the form of lecture-based instruction (Mifflin & Price, 2001). Katz and Chard (1989) asserted that the project-method of learning is “complementary and supplementary to other aspects of the curriculum” (p. 133).

Content Coverage

Ensuring that students receive instruction that “covers the content” is still a major concern for educators today. This is another concern about using a project-based curriculum.

Care must be taken to ensure that the content brought out by the projects is part of the mandated curriculum. With increased accountability through standardized testing, a project-based curriculum must be monitored closely for content coverage and supplemented appropriately. It is with Bagley's caution in mind that the project-based curriculum has been expanded in this dissertation research to include not only projects as defined by Kilpatrick (1918), but also a measure of lecture-based instruction.

The project-based learning environment also takes more time than a lecture-based learning environment, which is another concern. In order to provide students enough time to explore problem situations, come up with plans for solutions, receive feedback, make revisions, put together and give presentations, there is less time for lectures and content coverage. Once again the concern is whether enough of the content will be covered. Finding the right amount of project work that complements lecture-based instruction is an important consideration when undertaking a project-based curriculum.

Assessment in Project-based Learning

Summative and formative assessments are important features in PBL. Summative assessment measures learning outcomes at the end of a unit. Chapter tests or unit quizzes are common examples of summative assessments used in traditional instruction. Summative assessments are important since they measure what the students know and provide them feedback on content mastery. Formative assessment, on the other hand, is a means for providing feedback to students as they progress through various stages of their work. As students make improvements in solution, either through feedback from the teacher or through their own developing understanding, they gain a deeper understanding of the material and remain engaged

with the problem and content. Formative assessment is crucial to a project-based learning environment.

Formative Assessment

Frequent opportunities for feedback help students know if they are on a right track, not necessarily the one and only right track, but a right track nonetheless. When students work in groups they learn how to work collaboratively and effectively with others towards a common goal (Milner-Bolotin, 2001). Opportunities for contact with the teacher during this group-working process are essential in order for the teacher to determine if groups are working together well.

Rottier and Ogan (1991) recommended that students change groups when the project or activity changed. They rationalized that students need to learn to work with many different types of people. Students potentially would interact with peers from other ethnic, race, cultural, and religious backgrounds. They also recommend that group sizes be kept relatively small. Four or fewer students per group are ideal. They recommend four because students can break off into pairs to work on subtasks and then reform the group later.

Frequent formative feedback gives students the opportunity to make revisions in their thinking. Feedback provides students with two basic things: feedback about their group's particular solution and feedback about their group's dynamic. Meeting with groups regularly is essential in order to determine if groups are meeting their goals. Milner-Bolotin (2001) found that when students were left to their own devices they came up with rather broad questions to pursue. She found that teachers had to work closely with groups in order to help them narrow their focus. This type of ongoing teacher feedback is essential to problem-based instruction.

Meeting with students individually is also important. Benbow and McMahon (2001) found that formative feedback in the form of 5-minute conferences with each individual student allowed the instructors to discern if student-learning groups were functioning well. They asked students how they felt about individual groupmates' contributions and about their own individual contributions. This type of one-on-one session not only ensured that groups were working effectively but also ensured that every individual's needs were being met.

Reflections

Student-written reflections are another means for assessing student progress and growth (Beyer, 1993). Reflections help students explain their problem-solving processes and include any problems that arose during the project. Reflections also help students organize their thoughts as to their own personal contributions to the group, their groupmates' contributions to the group, and the overall problem-solving processes.

Rubrics

Rubrics are an essential method for providing feedback. Rubrics provided to students before the project begins inform them about the criteria on which they will be graded. Students need to understand that individual accountability is as important as group accountability (Leiken & Zaslavsky, 1999). Students who receive feedback concerning their individual and group performances come to understand that the process is as important as the solution to the problem (Moskal, 2000). Clearly laid out grading rubrics help alleviate misunderstandings in expectations before projects even begin (Moskal, 2000).

Teachers

Keeping students on track, focused, and working well within their groups is the prime directive of the teacher working in a project-based classroom. Teachers not only dole out appropriate content when necessary, but also act as group facilitators when groups seem to be dysfunctional. Teachers guide students on choosing feasible topics, finding sources, analyzing data, and making conclusions (Katz & Chard, 1989). Frequent feedback to students on both content and group dynamics is the key to a successful project-based learning experience.

CHAPTER 3 METHODOLOGY

A search of the literature revealed that there are increasing shortages in many science, technology, engineering, and mathematics professional fields. Although women's participation in STEM careers has increased over the years, the proportion of women is nowhere near that of men. And although men outnumber women in these fields the literature revealed that men from the United States do *not* participate in great enough numbers to fill the number of STEM professional vacancies. International men and women are making up these differences in greater and greater numbers.

Research Questions

The research questions probed into the following themes: Students' intended STEM endeavors, perceived usefulness of mathematics, perceived competence in mathematics, and levels of achievement. The treatment group refers to the group that participated in the project-based mathematics curriculum. The control group refers to the group that received only lecture-based instruction.

The research in this study determined whether students in the experimental group evidenced an increased positive change over time in attitudes regarding any of the following three constructs: plans for participation in future STEM endeavors, perceived usefulness, and perceived competence. The following alternate hypotheses were tested.

1. Did the students in the experimental group show a statistically significant positive change in attitudes regarding plans for future participation in STEM endeavors when compared to the change in attitudes of the control group?

2. Did the students in the experimental group show a statistically significant positive change in attitudes regarding perceived usefulness of mathematics when compared to the change in attitudes of the control group?
3. Did the students in the experimental group show a statistically significant positive change in attitudes regarding perceived competence in mathematics when compared to the change in attitudes of the control group?
4. Did the students in the experimental group and the students in the control group have any significant differences in their academic achievement as measured by their respective semester examinations?

Participants

The participants in the study were 99 middle school-aged girls and boys currently enrolled in an Honors Algebra 1 or an Algebra 1 mathematics course at a private college preparatory school in Central Florida. The students in these courses were in either grade 7 or grade 8. The coed school consisted of grade 6 through grade 12 with almost all graduating seniors going on to college or military academy. The school was comprised of 801 students with approximately the same number of males (51%) as females (49%). The ethnic breakdown of the school showed 78.8% Caucasian, 8.8% Asian, 6.5% Hispanic, 5.4% African American, 0.4% American Indian, and 0.1% Eurasian. The average SAT score for the students was 1206.

Due to the necessity of using intact classroom groups, the number of students in the experimental group and the number of students in the control group was not equal. Approximately 61 students received a project-based curriculum (also known as the treatment group or experimental group) and approximately 38 students received lecture-based instruction that did not include the project-based curriculum (the control group). The project-based curriculum received by the treatment group consisted of a learning environment in which projects were used to help students make connections between content and application of content. This group also received lecture-based instruction. The control group received lecture-

based instruction. Several factors influenced how students were placed in their classes, so the classes were intact groups. The classes as a whole, however, were randomly selected for either the experimental or control group. The school attempted to keep the number of boys and the number of girls fairly equal in each class.

The headmaster of the school in which this study took place was asked to sign an informed consent form (See Appendix A for all consent forms) in order for the study to take place at the institution. Once this was signed parental permission (Appendix A) was necessary in order for the students to participate since the participants were underage. A permission slip was mailed home to the students enrolled in the Algebra and Honors Algebra classes before school began in the fall in order for parents or guardians to give permission for their students to participate in the study. The students were also given an assent to participate in the study form (Appendix A) before the study began. And finally, the teachers involved in the study also signed an informed consent form (Appendix A). All of these consents, permissions, and assents are required by the University of Central Florida Institutional Review Board (UCFIRB).

Procedures

Pre-Survey

A Likert-scale questionnaire (See Appendix B) developed by the researcher was administered to all the participants. A first-draft of the questionnaire was administered to Trinity middle-school students during the preceding school year in order to determine reliability and validity. Factors were analyzed and the questionnaire was modified in order to attempt to measure the following constructs:

1. The students' future plans pertaining to their future science, technology, engineering and mathematics pursuits.
2. The students' level of perceived usefulness of mathematics.
3. The students' perceived competence in mathematics.
4. Personal information such as grade, sex, parents' occupations, and their own predicted future occupations.

Treatment

The Four Projects

The experimental participants participated in a semester-long, project-based mathematics curriculum in their year-long Honors Algebra 1 or Algebra 1 classes. This experimental group of students was divided up into small groups of approximately four or five students within their respective classes. Milner-Bolotin (2001) suggested that students who had the opportunity to self-select their own groups displayed more ownership of the projects, and so for the very first project, students were allowed to self-select their group membership. However, as the projects changed the group membership also changed.

The first three projects in the semester were teacher selected (See Table 1 for the Outline of Projects). Students were able to choose their fourth project from a list of suggested topics. The first three projects "set the stage" for the final project and allowed students more control. Henry (1994) asserted, "Students who have some kind of control over planning of their learning are also more likely to reflect on what they need, discover how to tailor approaches to suit them and get satisfaction that comes from initiating, planning and seeing through a project" (p.52). Milner-Bolotin (2001) found that students' initial interest in a project topic had a significant impact on their motivation. She found that even if students did not pick the topic, they had good motivation

while working on the project if they had an interest in the topic. The only criterion for a student-selected project was that it had to bring out some form of mathematics. The hope was that the students would pursue mathematically-rich projects in which they would experience mathematics in an applied fashion.

Table 1
Outline of Projects

Week # (17-week semester)	Problem/Project	Mathematics Brought Out
1 & 2	<u>Flagpole:</u> Students estimated the height of the flagpole on campus.	Similar figures (triangles), proportions, right-triangle trigonometry.
3, 4, & 5	<u>Paper Airplanes (R&D):</u> Students created a paper airplane and recorded distance and time flown. Students researched aerodynamics and came up with new designs to retest.	Median, mean, interquartile range, comparative boxplots, estimating rate of speed through measuring distance and time.
6, 7, 8, & 9	<u>Bridge Building:</u> Students first estimated the distance across the canal. Students then explored different types of bridges as they designed a walking bridge to cross over the canal.	Similar figures (triangles), proportions, right-triangle trigonometry, scale factor, proportions.
10, 11, 12, & 13	<u>Ecology</u> Saving Resources. Students picked their own projects from a list. Potential projects came from <i>50 Simple Things Kids Can Do to Save the Earth</i> by the Earth Works Group (1990). One project might include an evaluation of the benefits of recycling.	This varied by project. Examples included: Volume, graphing, problem solving, equations, proportions, scale factor.
14, 15, 16, & 17	Project wrap-ups and discussions. Curriculum content coverage. Semester Exam Review	

Henry (1994) suggested that project-based instruction should imitate apprenticeship. In an apprenticeship, she says, apprentices “are gradually introduced to the skills involved and then given considerable practice in the various skills involved before being asked to undertake a ‘project’ and even then it is generally under close supervision” (p. 20). All of the projects began with class discussions. These discussions helped frame the problem and allowed students to share what they already knew about the topic. This in turn informed the teachers as to how much the students already knew (Katz & Chard, 1989).

The first project, the flagpole project, (See Appendix C) was designed as an “icebreaker project” in which the students learned the method of project-based instruction. The students self-selected their project groups and were presented with the problem - to find the height of the flagpole on campus. They were then left to their own devices to come up with a method for solving the problem. They were introduced to the grading rubric and learned what was expected of them in terms of planning the solution, executing and revising the solution, and writing up and presenting the solution to their classmates. They also learned quickly that the teacher took on the role of facilitator or consultant, and the bulk of the work and thinking was left to them.

The projects became more and more open-ended as the semester progressed. The second project – design a paper airplane, test its flight, and then research and redesign the airplane – (See Appendix D) was intended to give the students more freedom in problem solution. Students received experience in the research and development (R&D) process as they researched aerodynamics in order to understand how a better airplane might be designed. The third project – bridge building - (See Appendix E) was increasingly more unstructured. The students were asked to design a bridge to cross the canal on campus. They first had to estimate the distance across the

canal. The design of the bridge was to be based on their groups' research about bridges. How they chose to present the "best" bridge design was left entirely up to the students.

The fourth project – ecology - (See Appendix F) was one in which the students picked a project from a general list of ecology projects. Students were given a sample list of projects from the book *50 Simple Things Kids Can Do to Save the Earth* (Earth Works Group, 1990). This resource describes ways that young people can help improve the environment. Although the general topic was chosen for the students in this fourth project, the students had to sift through many possibilities and select their own project. Students had to propose, develop, and execute their own project. The students were free to choose any project they wished from the list or come up with their own ecology-themed project. The one stipulation for the projects was that the projects must reflect some kind of mathematics. This scheme of increasing student autonomy follows the basic scheme Henry (1994) suggested about apprenticeships.

The flagpole project was chosen from a project the teachers had successfully tried out the previous school year. The other projects came from individual and mutual teacher brainstorming sessions, from colleague suggestions, and from the book, *50 Simple Things Kids Can Do to Save the Earth* (Earth Works Group, 1990).

Class Time Allocation

Many of the projects took from two to four weeks to complete. This length of time was necessary in order to provide students enough time to think and rethink their solutions, get adequate feedback from their teachers, and put together presentations. Henry (1994) recommended that "thinking time" (p. 58) be built into the schedule. The experimental group used class time in the library and in the computer lab for researching their topics. Not all of class

time, however, was dedicated to the projects. Students also received lecture-based mathematics instruction as the semester progressed, not only to ensure that the mandated curriculum was covered, but also to allow the teachers the opportunity to “cover” enough algebra content in order to provide the students with the mathematical tools necessary for solving their problems. Mathematics instruction also took place *during* the project sessions as the need arose in order for the students to move forward on their projects.

The control group received lecture-based instruction with no special project-based curriculum. This lecture-based instruction included primarily lecture-based teaching methods followed by textbook exercises.

Teachers

The two algebra teachers participating in the study are both veterans in the classroom each with at least 18 years of classroom experience. Both teachers have taught primarily through the use of the lecture-based method of instruction in which students take notes and then work on exercises from the textbook or worksheets. Both teachers have used cooperative learning techniques in their classes, but neither has taught a course using project-based learning. The teachers met formally on a regular basis to discuss how the project-based implementation was proceeding.

Assessment

Students received a final grade for each project as evaluated through rubrics (See Appendix G). Students were given a blank copy of the grading rubric before the projects began. Clearly laid out grading rubrics help alleviate misunderstandings in expectations before projects

even begin (Moskal, 2000). The rubrics measured four aspects of the students' work including student planning, execution of the plan, actual solution, and presentation. As each project progressed, students communicated with their teacher on both an informal and formal basis. Informally, groups and individual students interacted with the teacher and the teacher helped the groups stay on task. Formally, teachers met with each student for a short "5-minute conference" in order to check on group dynamics (Benbow and McMahon, 2001). Individuals were asked how each project was proceeding and asked to comment about how the group worked together. Students were also asked to write a reflection (See Appendix H) about the project once all groups' presentations were completed. These reflections required students to assess their own contributions to the group, assess their groupmates' contributions to the group, and assess the overall problem-solving process.

Students reported their findings through group presentations. The presentations provided an opportunity for students to communicate mathematically (NCTM, 2000) to the rest of the class and provided students an opportunity to share their problem-solving processes and analyses. The students were also required to hand in individual write-ups for each of the five projects.

Post-Survey

A Likert-scale post-questionnaire (See Appendix E), also developed by the researcher, was similar to the pre-questionnaire with a few added questions. The post-questionnaire was delivered to all participants. The questionnaire attempted to re-measure the following constructs.

1. The students' future plans pertaining to their future science, technology, engineering, and mathematics pursuits.
2. The students' level of perceived usefulness of mathematics.

3. The students' perceived competence in mathematics.
4. Experiences this year about the project-based curriculum and how the participants felt about their participation in the study.

Data Analysis

The data analysis was done using a mixed methods approach. Both quantitative and qualitative analyses were done. The quantitative analysis examined the results of the pre- and post-surveys from both the experimental and the control groups. Data were compared to determine if the students in the experimental group evidenced a positive change over time in attitudes regarding the three constructs from the questionnaires. The constructs are perceived usefulness, perceived competence, and plans for participation in future STEM endeavors. The qualitative analysis examined the experience of students' participation in a problem-based learning environment. Emergent themes were uncovered and explored. The students' level of achievement on their semester exam was also examined to see if there were any appreciable differences in achievement between the experimental group and the control group.

This research experiment must be considered a quasi-experimental design since the experimental and control groups were intact groups and students were not assigned at random to these groups (Shavelson, 1996; Campbell & Stanley, 1963). This particular quasi-experimental design is a nonequivalent pre-test/post-test control group design (Shavelson, 1996; Campbell & Stanley, 1963).

Construct validity for these three constructs was established using factor analysis (Hair, Tatham, Anderson, & Black, 1998) using the computer statistical package, Statistical Program for the Social Sciences (SPSS, version 12, 2003). The questionnaires were also evaluated in

terms of reliability by using SPSS to calculate a Cronbach Alpha coefficient. The reliability coefficient helped determine how internally consistent the items in the questionnaire were.

Quantitative Evaluation

Significance tests using 2X2X2 (group x sex x tests) repeated measures (pre- and post-tests) analysis of variance (ANOVA) (Shavelson, 1996) determined if there were any significant interaction effects in each of the constructs. A *t*-test determined if there was a significant difference in achievement between the experimental and control groups. The following tests were conducted.

Changes in Constructs

1. The attitude scores from the pre- and post-questionnaires of the students in the experimental group were compared to the students in the control group to determine if there was evidence of a positive change over time in attitudes regarding plans for participation in future STEM endeavors.
2. The attitude scores from the pre- and post-questionnaires of the students in the experimental group were compared to the students in the control group to determine if there was evidence of a positive change over time in attitudes regarding perceived usefulness of mathematics.
3. The attitude scores from the pre- and post-questionnaires of the students in the experimental group were compared to the students in the control group to determine if there was evidence of a positive change over time in attitudes regarding perceived competence in mathematics.

Achievement

4. The experimental group and the control group were compared to determine if there were any significant differences in their academic achievement as measured by their respective semester examinations.

Qualitative Evaluation

A qualitative investigation was conducted in order to help interpret the quantitative results. Qualitative research is used for exploring a topic in more depth (Gay & Airasian, 2000). Student written responses from the post-questionnaire, the formal 5-minute student interviews, student reflections, the students' four projects, and informal conversations with students were examined in order to glean any common reactions or themes. The formal and informal teacher interviews were also explored for pertinent information.

Data were interpreted qualitatively using a four-step process. Once the student and teacher qualitative data were gathered, the data were re-read, classified, categorized, and interpreted (Gay & Airasian, 2000). Triangulation is a method used in qualitative research to search for common themes in the data (Gay & Airasian, 2000). Triangulation is used to find regularities in the data by crosschecking information across several different sources of data. Both the quantitative and qualitative data helped in the interpretation of results of this research project.

Limitations

The results of this study relied heavily on the quality of projects selected. Attempts to replicate this study may yield different results depending on the quality and quantity of projects chosen.

Another limitation is based on the particular participants chosen for the study. The participants are from a primarily white, competitive, private college-preparatory school in the Central Florida area. These students usually take four years of high school mathematics and four

years of high school sciences. Consequently, there may be minimal changes in their mathematics and science choices in high school.

A third limitation of the study was the relatively small sample size (N= 99).

A fourth limitation was that although there were two teachers involved in the study, the researcher was one them. This may have lead to bias and subjectivity since the researcher/teacher was so invested in the study.

CHAPTER 4

RESULTS AND DATA ANALYSIS

The primary purpose of this research was to investigate whether a project-based mathematics curriculum would increase middle school students' intentions to pursue STEM endeavors in the form of increased STEM courses, college majors, and intended careers. Also investigated were whether a project-based mathematics curriculum would influence middle school students' attitudes in the perceived usefulness of mathematics, attitudes in their perceived competence in mathematics, and their academic achievement.

The Research Questions

Research questions explored students' intended future STEM endeavors, perceived usefulness of mathematics, perceived competence in mathematics, and achievement. The research questions were as follows.

1. Did the students in the experimental group show a statistically significant positive change in attitudes regarding plans for future participation in STEM endeavors when compared to the change in attitudes of the control group?
2. Did the students in the experimental group show a statistically significant positive change in attitudes regarding perceived usefulness of mathematics when compared to the change in attitudes of the control group?
3. Did the students in the experimental group show a statistically significant positive change in attitudes regarding perceived competence in mathematics when compared to the change in attitudes of the control group?
4. Did the students in the experimental group and the students in the control group have any significant differences in their academic achievement as measured by their respective semester examinations?

The Pre- and Post-Questionnaires

The pre- and post-questionnaires were evaluated in terms of reliability and factor analysis. The reliability coefficient determined how internally consistent the items were in each of the questionnaires. Factor analyses were done on the data in order to determine the underlying structures among the items. The ultimate goal was to obtain theoretically meaningful factors (constructs) while ensuring that the observed patterns were conceptually valid and appropriate for study (Hair, Tatham, Anderson, Black, 1998).

Reliability

The Cronbach Alpha coefficient was calculated using the Statistical Program for the Social Sciences, Version 12 (SPSS, 2003). The reliability coefficient measured the internal consistency among the questionnaire items. Since the questionnaires contained items ranked on Likert scales, both the pre-questionnaire and the post-questionnaire were evaluated with the polygamous Cronbach alpha coefficient. Respondents' ratings of statements in the pre-questionnaire showed very good reliability for the middle school students to whom it was given, with the reliability coefficient of .8565 ($n = 99$, number of items = 20). A review of the corrected item-total correlations showed that none of the variables were negatively correlated with the total, and no variable's elimination would have changed the coefficient significantly.

Respondents' ratings of statements in the post-questionnaire also showed very good reliability for the middle school students to whom it was given, with the reliability coefficient of .8770 ($n = 99$, number of items = 20). A review of the corrected item-total correlations again showed that none of the variables were negatively correlated with the total, and no variable's elimination would have changed the coefficient significantly.

Construct Validity

Construct validity was established for both the pre- and post-questionnaires using factor analysis from SPSS. Three factors as originally conceived were (1) STEM endeavors, (2) perceived usefulness, and (3) perceived competence. The pre-questionnaire correlation coefficients were calculated using the promax (oblique rotations) factor correlation matrix and were large enough ($r = .241$, $r = .304$, $r = .484$) to make the oblique rotation preferable. The pre-questionnaire variables loaded as anticipated for each factor showing validity evidence of good internal structure. The post-questionnaire variables also loaded as anticipated for each factor. The post-questionnaire correlation coefficients were also calculated using the promax (oblique rotations) factor correlation matrix and were large enough ($r = .580$, $r = .323$, $r = .447$) to make the oblique rotation preferable. The items loaded according to intended conceptual underpinnings for both the pre-and post-surveys.

Survey Results

The means and standard deviations of the three constructs from the pre-survey for both the experimental and the control groups are presented in Table 2. The means and standard deviations of the three constructs of the post-survey for both the experimental and the control groups are presented in Table 3. The results of the pre- and post-surveys were compared to determine if the students in the experimental group evidenced a statistically significant positive change in attitudes regarding the three constructs when compared to the changes in attitudes of the control group.

Table 2
Means and Standard Deviations of the Three Constructs from the Pre-Survey

Pre-Survey	STEM Endeavors (Scale: 5-46)		Perceived Usefulness (Scale: 5-35)		Perceived Competence (Scale: 5-35)	
	Mean	SD	Mean	SD	Mean	SD
Experimental Group						
Girls (N=33)	23.79	6.12	30.18	3.23	26.94	4.66
Boys (N=28)	25.14	5.56	29.61	4.30	27.46	4.86
Both (N=61)	24.41	5.86	29.92	3.73	27.18	4.72
Control Group						
Girls (N=17)	24.88	6.70	31.12	2.23	28.53	3.88
Boys (N=21)	25.90	5.15	30.29	2.94	29.43	2.44
Both (N=38)	25.45	5.83	30.66	2.64	29.03	3.15

Table 3
Means and Standard Deviations of the Three Constructs from the Post-Survey

Post-Survey	STEM Endeavors (Scale: 5-46)		Perceived Usefulness (Scale: 5-35)		Perceived Competence (Scale: 5-35)	
	Mean	SD	Mean	SD	Mean	SD
Experimental Group						
Girls (N=33)	24.67	6.60	31.03	2.71	26.48	4.35
Boys (N=28)	25.96	6.06	31.54	3.21	26.75	4.79
Both (N=61)	25.26	6.34	31.26	2.99	26.61	4.52
Control Group						
Girls (N=17)	24.35	7.91	30.29	4.09	27.59	4.71
Boys (N=21)	28.24	5.10	30.67	3.41	27.81	3.56
Both (N=38)	26.50	6.70	30.50	3.68	27.71	4.05

The constructs are plans for participation in future STEM endeavors, perceived usefulness of mathematics, and perceived competence in doing mathematics.

The research experiment was considered to be a quasi-experimental design since the experimental and control groups were intact groups and the students had not been assigned at random to these groups (Shavelson, 1996; Campbell & Stanley, 1963). This particular quasi-experimental design is a nonequivalent pre-test/post-test control group design (Shavelson, 1996; Campbell & Stanley, 1963).

The statistical analysis necessary for a nonequivalent pre-test/post-test control group design using SPSS (SPSS, 2003) was a general linear model (GLM) repeated measures. The GLM repeated measures analyzes the differences between dependent variables that contain different measurement of the same attribute. In this case there were two different measurements that were the results from the pre-survey and the post-survey. Each of the three constructs was analyzed using the GLM repeated measures analysis for each treatment group.

Results Pertaining to STEM Endeavors

Students in the experimental group and the control group were asked questions concerning their intended future STEM endeavors (See Appendix A for the pre-questionnaire; See Appendix I for the post-questionnaire). For example, students were asked whether they would consider majoring in science, computers/technology, engineering or mathematics in college. They were also asked if they planned to take an AP mathematics course in high school or more than one mathematics course in college. The results of the pre- and post-surveys for the variable STEM Endeavors are listed in Table 4.

Table 4
STEM Endeavors - Means and Standard Deviations from the Pre- and Post-Surveys

	Pre-Survey STEM Endeavors (Scale: 5-46)		Post-Survey STEM Endeavors (Scale: 5-46)	
	Mean	SD	Mean	SD
Experimental Group (N=61)	24.41	5.861	25.26	6.34
	Mean	SD	Mean	SD
Control Group (N=38)	25.45	5.830	26.50	6.701

The results of the pre- and post-surveys were compared using SPSS (2003) GLM repeated measures to determine if the students in the experimental group evidenced a statistically significant positive change in attitudes regarding intended STEM endeavors when compared to the changes in attitudes of the control group. Both groups' results are graphed in Figure 3.

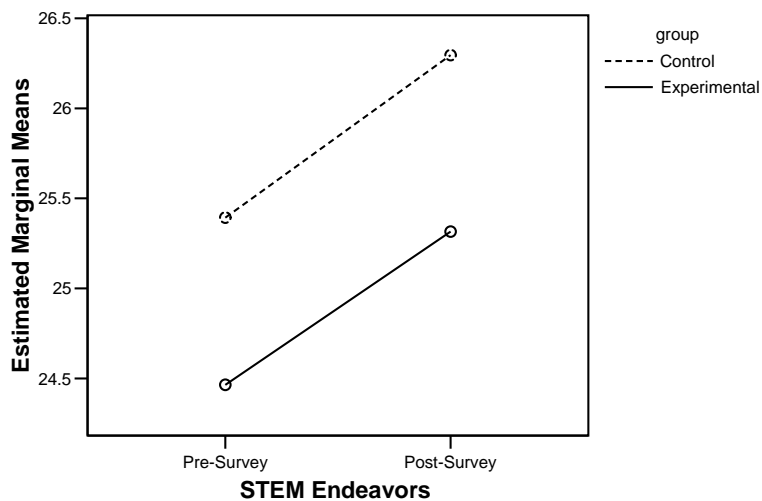


Figure 3: Changes in Attitudes Regarding Intended STEM Endeavors

Both the project-based experimental group and the control group showed an increase in their attitudes pertaining to the intended STEM endeavors. Mauchly's test of sphericity was not significant and sphericity, therefore, can be assumed. The GLM repeated measures analysis indicated there was no statistically significant increase in attitudes pertaining to STEM Endeavors when the experimental (project-based) group was compared to the control group $F(1,97) = .002, p > .05$. The increase in the project-based group was about the same as the control group as indicated by the graph in Figure 3.

Intended Careers

The careers anticipated by the participants included healthcare, science, legal occupations, architecture, computers/technology, entertainment, engineering, journalism, business, professional athlete, chef, fashion design, and aviation. The category of homemaker was later added in order to accommodate the students' write-in choices for the careers of their parents.

Experimental Group

The frequencies and percentages for pre- and post-treatment career choices for the experimental group are listed in Table 5 below. The most popular intended career choice for the experimental group in both the pre- and post-surveys was healthcare. Healthcare-related careers included doctors, surgeons, dentists, and nurses. Approximately 20% (12 students) of the students in the experimental group chose healthcare in the pre-survey and this figure remained constant in the post-survey. Science, Technology, and Engineering intended careers combined for approximately 11% (7 students) of the pre-survey and a slightly, but not significantly, higher

15% (9 students) of the post-survey. Interestingly, more students in the experimental group's pre-survey indicated a desire to become professional athletes (6.56% or 4 students) than to become scientists and engineers combined (4.92% or 3 students). This included both girls and boys.

Table 5
Experimental Group Intended Career Choices (Pre-and Post-Survey)

Experimental Group	Pre-Survey		Post-Survey	
	Frequency	Percent	Frequency	Percent
Healthcare	12	19.67%	12	19.67%
Business	8	13.11%	8	13.11%
Legal Occupations	8	13.11%	6	9.84%
Entertainment	5	8.20%	7	11.48%
Architecture	4	6.56%	2	3.28%
Computer/Technology	4	6.56%	1	1.64%
Education	4	6.56%	1	1.64%
Professional Athlete	4	6.56%	5	8.20%
Fashion Designer	3	4.92%	3	4.92%
Undecided	3	4.92%	3	4.92%
Journalism	2	3.28%	4	6.56%
Science	2	3.28%	4	6.56%
Engineering	1	1.64%	4	6.56%
Chef	1	1.64%	0	0.00%
Homemaker	0	0.00%	1	1.64%
Total	61	100.00%	61	100.00%

The career choices made by students in the experimental group varied little from pre-survey to post-survey as evidenced in the side-by-side bar graph in Figure 4. The second most popular intended career for the experimental group in both the pre- and post-surveys was a career in business.

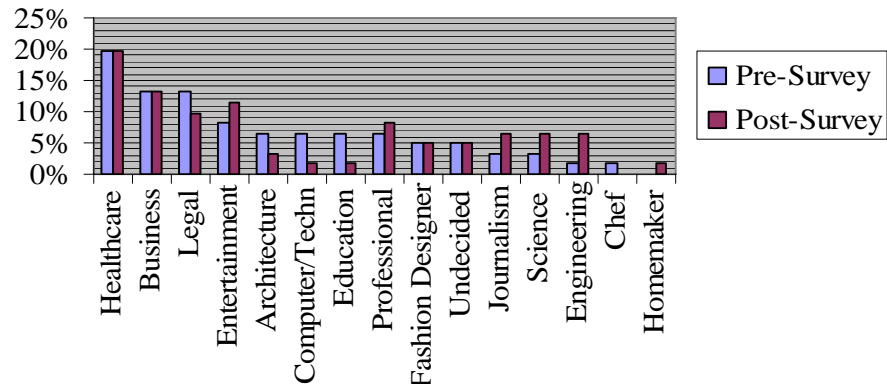


Figure 4: Pre- and Post-Survey Career Choices (Experimental Group)

Control Group

The frequencies and percentages for pre- and post-treatment career choices for the control group are listed in Table 6 below.

**Table 6
Control Group Intended Career Choices (Pre-and Post-Survey)**

Control Group	Pre-Survey		Post-Survey	
	Frequency	Percent	Frequency	Percent
Healthcare	10	26.32%	11	28.95%
Science	6	15.79%	5	13.16%
Legal Occupations	4	10.53%	4	10.53%
Architecture	3	7.89%	3	7.89%
Computer/Technology	3	7.89%	1	2.63%
Entertainment	3	7.89%	3	7.89%
Engineering	2	5.26%	2	5.26%
Journalism	2	5.26%	1	2.63%
Business	1	2.63%	1	2.63%
Professional Athlete	1	2.63%	2	5.26%
Chef	1	2.63%	0	0.00%
Fashion Designer	1	2.63%	2	5.26%
Aviation	1	2.63%	1	2.63%
Education	0	0.00%	1	2.63%
Homemaker	0	0.00%	0	0.00%
Public Service	0	0.00%	1	2.63%
Total	38	100.00%	38	100.00%

The most popular intended career choice for the control group, as it was with the experimental group, was healthcare. Approximately 23% (10 students) of the students in the control group chose healthcare in the pre-survey with a slight increase to approximately 29% (11 students) in the post-survey. Science careers came in second place for the control group in both the pre-survey (15.79% or 6 students) and the post-survey (13.16% or 5 students). In fact, science, technology, and engineering intended careers combined for approximately 29% (11 students) of the pre-survey 21% (8 students) of the post-survey for the control group.

A side-by-side bar graph depicting the comparison between the control groups' pre-survey choices of intended careers versus the post-survey choices of intended careers is presented in Figure 5 below. Clearly, the career choices made by students in the control group varied little from pre-test to post-test.

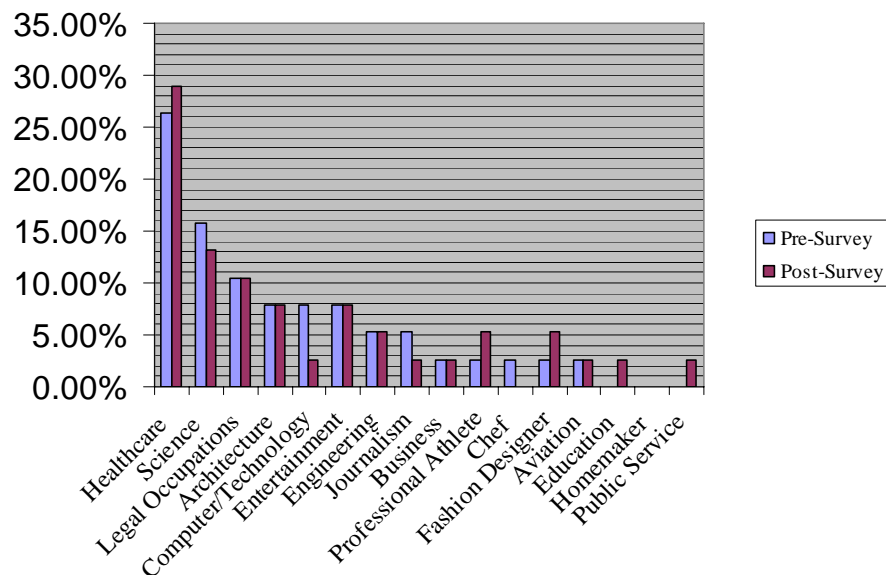


Figure 5: Pre-and Post-Survey Career Choices (Control Group)

Results Pertaining to Perceived Usefulness of Mathematics

Students in both groups were asked questions concerning their attitudes of the perceived usefulness of mathematics (See Appendix A for the pre-questionnaire; See Appendix I for the post-questionnaire). For example, students were asked whether they or their parents considered mathematics useful in their daily lives. Students were also asked whether they thought people who were not engineers, scientists, or mathematicians used mathematics. The results of the pre- and post-survey for the variable *usefulness* are listed in Table 7.

The results of the pre- and post-surveys were compared to determine if the students in the experimental group evidenced a statistically significant positive change in attitudes regarding perceived usefulness of mathematics when compared to the changes in attitudes of the control group.

Table 7
Usefulness - Means and Standard Deviations for Pre- and Post-Surveys

	Pre-Survey Perceived Usefulness (Scale: 5-35)		Post-Survey Perceived Usefulness (Scale: 5-35)	
	Mean	SD	Mean	SD
Experimental Group (N=61)	29.92	3.73	31.26	2.99
	Mean	SD	Mean	SD
Control Group (N=38)	30.66	2.64	30.50	3.68

Both groups' results are graphed in Figure 6.

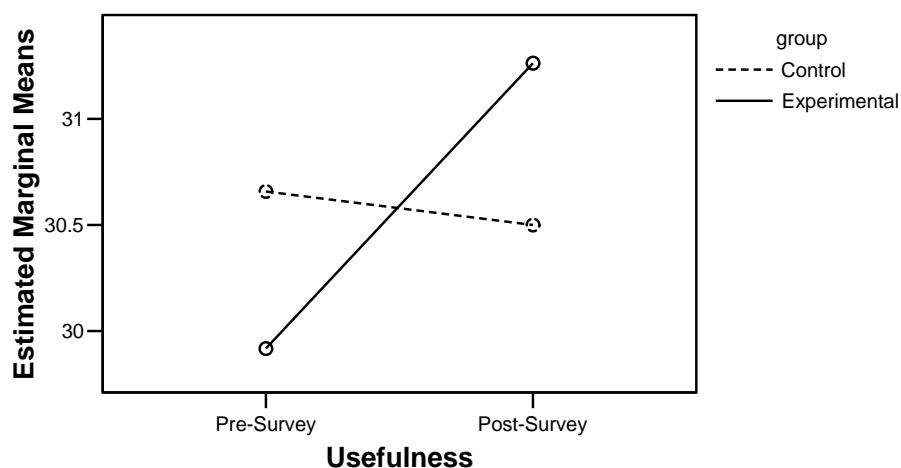


Figure 6: Changes in Attitudes Regarding Perceived Usefulness

Figure 6 above indicates that the experimental group exhibited a positive increase in attitudes toward perceived usefulness of mathematics while the control group exhibited a decrease in attitudes towards perceived usefulness. Mauchly’s test of sphericity indicated that sphericity could be assumed. The GLM repeated measures analysis indicated there was a statistically significant increase in attitudes pertaining to perceived usefulness when the experimental (project-based) group was compared to the control group $F(1, 97)=5.14, p=.022$. The project-based students showed a significant increase in their attitudes pertaining to the perceived usefulness of mathematics. Investigating further, the overall effect for this interaction was small with the partial eta squared equal to .053 indicating that only 5.3% of the variance in attitude change can be explained by the problem-based instruction. Therefore, although there was a detectable change in attitude in the experimental group with regard to their attitudes concerning the perceived usefulness of mathematics, the effect is a small one.

A possible variable that may need exploring is class size. The average class size of each experimental group was approximately 20, while the average class size of each control group was approximately 13. Perhaps the effect size of the usefulness variable might be greater given a smaller average class size. Research has indicated that successful implementation of new curricula depends partly on smaller classes (Covell, O'Leary, & Howe, 2002). Another potential variable that may have influenced the small effect size was the relatively short duration of the study. The study took place over one semester. Perhaps if the study were expanded to an entire year the results may have shown more practical significance.

Results Pertaining to Perceived Competence in Mathematics

Students in both groups were asked questions concerning their perceived competence in doing mathematics (See Appendix A for the pre-questionnaire; See Appendix I for the post-questionnaire). For example, students were asked whether they felt confident learning the mathematics in the next chapter in their math classes and whether they felt able to learn Calculus in the future. The results of the pre- and post-survey for the variable *competence* are listed in Table 8.

The results of the pre- and post-surveys were compared to determine if the students in the experimental group evidenced a statistically significant positive change in attitudes regarding perceived competence in mathematics when compared to the changes in attitudes of the control group. Both groups' results are graphed in Figure 7.

Table 8
Competence - Means and Standard Deviations for Pre- and Post-Surveys

	Pre-Survey Competence (Scale: 5-35)		Post-Survey Competence (Scale: 5-35)	
	Mean	SD	Mean	SD
Experimental Group (N=61)	27.18	4.72	26.61	4.52
	Mean	SD	Mean	SD
Control Group (N=38)	29.03	3.15	27.71	4.05

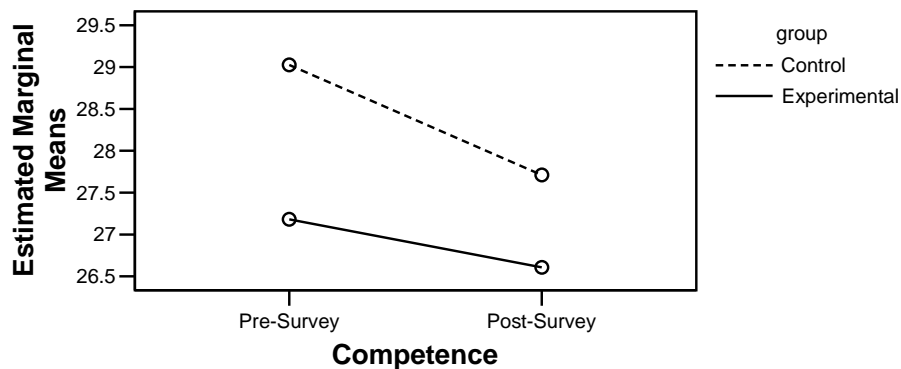


Figure 7: Changes in Attitudes Regarding Perceived Competence

Neither the project-based experimental group nor the control group showed any increase in students' attitudes pertaining to the perceived usefulness of mathematics. In fact, each group showed a decrease in their perceived competence. Mauchly's test of sphericity indicated that sphericity could be assumed. The GLM repeated measures analysis indicated there was no

statistically significant increase or decrease in attitudes pertaining to perceived competence when the experimental (project-based) group was compared to the control group $F(1,97)=.868, p>.05$.

Results Pertaining to Achievement

The students' levels of achievement on their semester exams were also examined. Both the experimental and control groups covered the same curriculum content. Although adequate content coverage for the experimental group was a major concern before beginning the study, the content was adequately covered with both groups based on the progress both treatment groups made in the teachers' respective Algebra curriculum guides. The students in both groups covered the same amount of pages in their respective textbooks as well. Both the experimental and control groups received lecture-based instruction, but the experimental group also received project-based instruction.

The means and standard deviations of the experimental and control groups' semester examinations are listed in Table 9.

Table 9
Achievement Results from Semester Examinations

Semester Examinations		
Experimental Group (n = 61)	Mean	SD
	85.2	8.82
Control Group (n=38)	Mean	SD
	86.5	7.47

A t-test was used to compare the means of the experimental and control groups' semester exams. Levene's Test for equal variances indicated that equal variances can be assumed $F(97) = 2.603, p > .05$. The experimental group ($M = 85.2, SD = 8.82, n=61$) and the control group ($M = 86.5, SD = 7.47, n = 38$) showed no appreciable differences in achievement at the .05 significance level, $t(97) = 0.743, p > .05$.

Gender Issues

The data from both the pre- and post-surveys were also examined in terms of gender differences with respect to the three constructs – intended STEM endeavors, perceived usefulness of mathematics, and perceived competence in mathematics. Achievement was also examined in terms of gender differences. One set of data was analyzed to determine if there were any appreciable differences between girls in the experimental group and girls in the control group in terms of changes in attitudes. The experimental group's boys and the control group's boys were similarly examined. These tests were run in order to determine if treatment group influenced the girls' reactions.

Another set of statistical tests was done to determine if there were any appreciable differences between boys and girls within each treatment group. The experimental girls were compared with the experimental boys. Similarly, the control group girls were compared to the control group boys. These tests were run in order to determine if either of the treatment groups influenced girls differently than boys in terms of significant changes in attitudes regarding the variables STEM endeavors, perceived usefulness, perceived competence, and achievement.

Between Treatment Groups - Girls versus Girls and Boys versus Boys

The means and standard deviations of girls and boys from the pre- and post-surveys for each treatment group are listed in Table 10 below. The results were compared to determine if the girls in the experimental group evidenced a statistically significant positive change in attitudes regarding the three constructs when compared to the changes in attitudes of the girls in the control group. The results of the pre- and post-surveys were also compared to determine if the boys in the experimental group evidenced a statistically significant positive change in attitudes regarding the three constructs when compared to the changes in attitudes of the boys in the control group.

Table 10
Means and Standard Deviations of Girls and Boys from the Pre- and Post-Surveys

	STEM Endeavors (Scale: 5-46)				Perceived Usefulness (Scale: 5-35)				Perceived Competence (Scale: 5-35)			
	Mean		SD		Mean		SD		Mean		SD	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
GIRLS												
Experimental Girls (N=33)	23.79	24.67	6.12	6.60	30.18	31.03	3.23	2.71	26.94	26.48	4.66	4.35
Control Girls (N=17)	24.88	24.35	6.70	7.91	31.12	30.29	2.23	4.09	28.53	27.59	3.88	4.71
BOYS												
Experimental Boys (N=28)	25.14	25.96	5.56	6.06	29.61	31.54	4.30	3.21	27.46	26.75	4.86	4.79
Control Boys (N=21)	25.90	28.24	5.15	5.10	30.29	30.67	2.94	3.41	29.43	27.81	2.44	3.56

STEM Endeavors

The results of the pre- and post-surveys were compared using SPSS (2003) GLM repeated measures to determine if there were any statistically significant positive changes in attitudes regarding intended STEM endeavors when the experimental and control groups, separated by gender, were compared.

Girls

The girls in the project-based experimental group showed an increase in their attitudes pertaining to intended STEM endeavors, while the girls in the control group showed a decrease (See Table 10 for means and standard deviations). Figure 8 shows the changes in attitudes over time for girls' intended STEM endeavors. Mauchly's test of sphericity was not significant and sphericity, therefore, could be assumed.

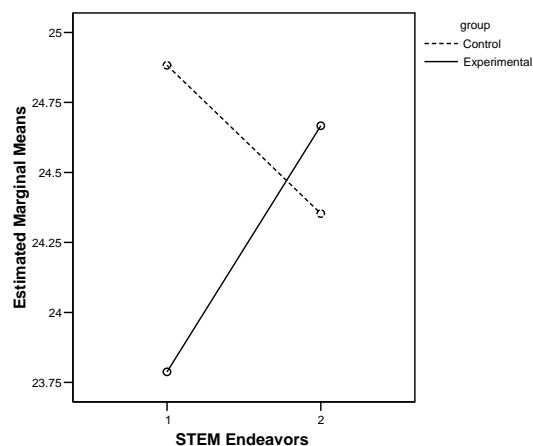


Figure 8: Changes in Attitudes Regarding Intended STEM Endeavors (Experimental Girls versus Control Girls)

Although there was a difference in direction of change, the GLM repeated measures analysis indicated there was no statistically significant difference in attitudes pertaining to STEM

endeavors when the girls in the experimental (project-based) group were compared to the girls in the control group $F(1,48) = .835, p > .05$.

Boys

Both the boys in the project-based experimental group and the boys in the control group showed an increase in their attitudes pertaining to intended STEM endeavors, (See Table 10 above for means and standard deviations). Figure 9 shows the changes in boys' attitudes over time for intended STEM endeavors. Mauchly's test of sphericity was not significant and sphericity, therefore, could be assumed. The GLM repeated measures analysis indicated there was no statistically significant difference in attitudes pertaining to STEM endeavors when the boys in the experimental (project-based) group were compared to the boys in the control group $F(1,47) = 1.029, p > .05$.

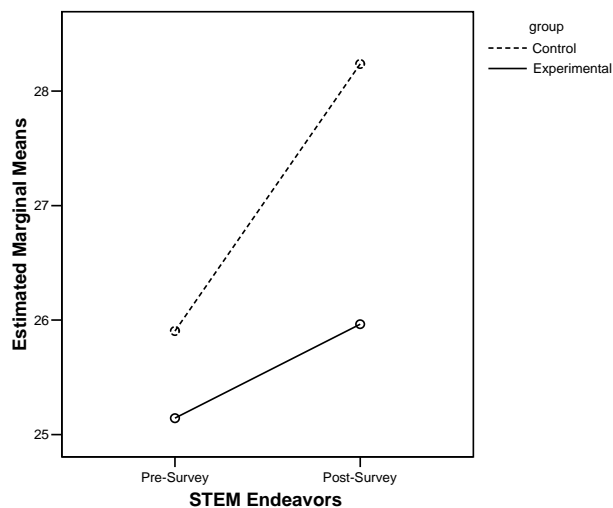


Figure 9: Changes in Attitudes Regarding Intended Stem Endeavors (Experimental Boys versus Control Boys)

Usefulness of Mathematics

The results of the pre- and post-surveys were compared using SPSS (2003) GLM repeated measures to determine if there were any statistically significant positive changes in attitudes regarding perceived usefulness when the experimental and control groups, separated by gender, were compared.

Girls

The girls in the project-based experimental group showed an increase in their attitudes pertaining to perceived usefulness of mathematics, while the girls in the control group showed a decrease (See Table 10 above for means and standard deviations). Figure 10 shows the changes in girls' attitudes over time for perceived usefulness of mathematics. Mauchly's test of sphericity was not significant and sphericity, therefore, could be assumed. Although there was a difference in direction of change, the GLM repeated measures analysis indicated there was no statistically significant differences in attitudes pertaining to perceived usefulness when the girls in the experimental (project-based) group were compared to the girls in the control group $F(1,48) = 3.007, p = .089$.

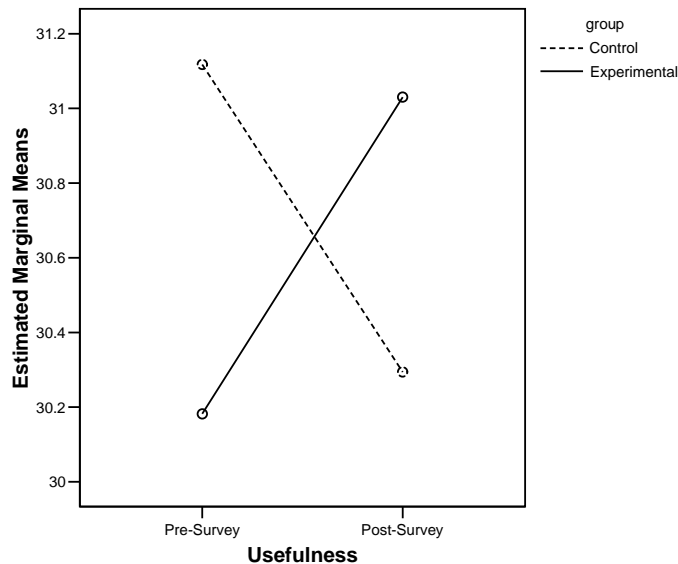


Figure 10: Changes in Attitudes Regarding Perceived Usefulness (Experimental Girls versus Control Girls)

Boys

Both the boys in the project-based experimental group and the boys in the control group showed an increase in their attitudes pertaining to perceived usefulness, (See Table 10 for means and standard deviations). Figure 11 shows the changes in boys' attitudes over time for perceived usefulness. Mauchly's test of sphericity was not significant and sphericity, therefore, could be assumed. The GLM repeated measures analysis indicated there was no statistically significant differences in attitudes pertaining to perceived usefulness when the boys in the experimental (project-based) group were compared to the boys in the control group $F(1,47) = 3.272, p = .077$.

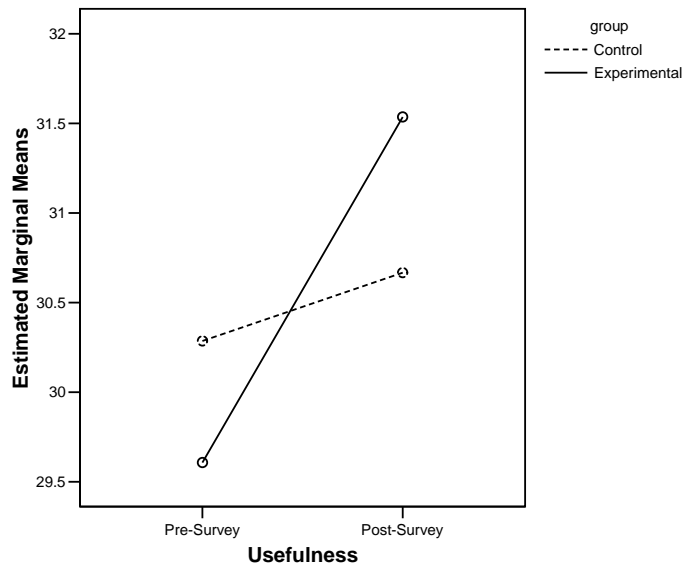


Figure 11: Changes in Attitudes Regarding Perceived Usefulness (Experimental Boys versus Control Boys)

Perceived Competence

The results of the pre- and post-surveys were compared using SPSS (2003) GLM repeated measures to determine if there were any statistically significant positive changes in attitudes regarding perceived competence when the experimental and control groups, separated by gender, were compared.

Girls

Both the girls in the project-based experimental group and the girls in the control group showed a decrease in their attitudes pertaining to perceived competence in doing mathematics, (See Table 10 above for means and standard deviations). Figure 12 shows the changes in girls' attitudes over time for their perceived competence. Mauchly's test of sphericity was not

significant and sphericity, therefore, could be assumed. The GLM repeated measures analysis indicated there was no statistically significant difference in attitudes pertaining to perceived competence when the girls in the experimental (project-based) group were compared to the girls in the control group $F(1,48) = .141, p > .05$.

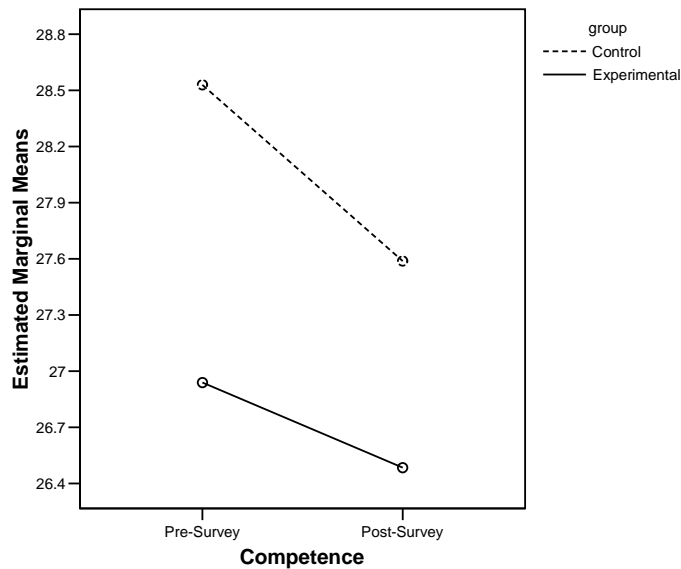


Figure 12: Changes in Attitudes Regarding Perceived Competence (Experimental Girls versus Control Girls)

Boys

Both the boys in the project-based experimental group and the boys in the control group showed a decrease in their attitudes pertaining to perceived competence in doing mathematics, (See Table 10 above for means and standard deviations). Figure 13 shows the changes in boys' attitudes over time for their perceived competence. Mauchly's test of sphericity was not significant and sphericity, therefore, could be assumed. The GLM repeated measures analysis

indicated there was no statistically significant difference in attitudes pertaining to perceived competence when the boys in the experimental (project-based) group were compared to the boys in the control group $F(1,47) = .867, p > .05$.

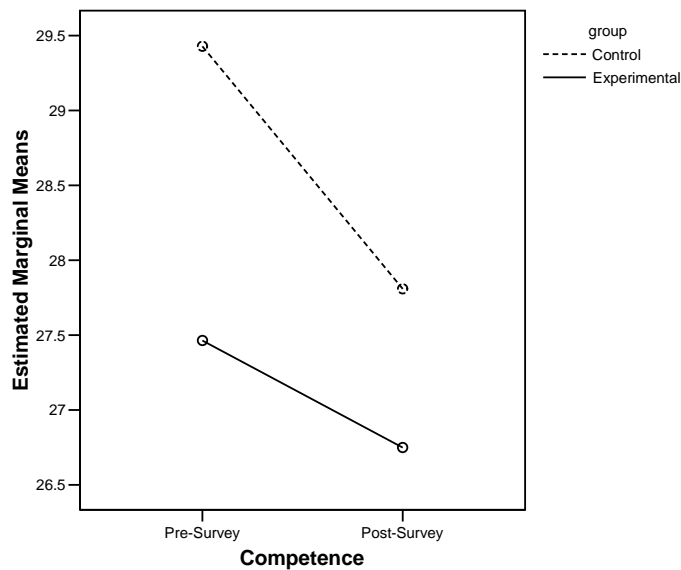


Figure 13: Changes in Attitudes Regarding Perceived Competence (Experimental Boys versus Control Boys)

Within Treatment Groups - Girls versus Boys

The results of the pre- and post-surveys were also compared to determine if the girls in the experimental group evidenced a statistically significant change in attitudes regarding the three constructs when compared to the changes in attitudes of the boys in the experimental group (See Table 10 above for means and standard deviations). The results of the pre- and post-surveys were also compared to determine if the girls in the control group evidenced a statistically

significant change in attitudes regarding the three constructs when compared to the changes in attitudes of the boys in the control group.

STEM Endeavors

The results of the pre- and post-surveys were compared using SPSS (2003) GLM repeated measures to determine if there were any statistically significant positive changes in attitudes regarding intended STEM endeavors when girls and boys within each treatment group were compared.

Experimental Group

Both the girls and the boys in the project-based experimental group showed an increase in their attitudes pertaining to intended STEM endeavors (See Table 10 above for means and standard deviations). Figure 14 shows the changes in experimental girls' and experimental boys' attitudes over time for intended STEM endeavors. Mauchly's test of sphericity was not significant and sphericity, therefore, could be assumed. The GLM repeated measures analysis indicated there was no statistically significant difference in attitudes pertaining to intended stem endeavors when the girls in the experimental group were compared to the boys in the experimental group $F(1,59) = .002, p > .05$.

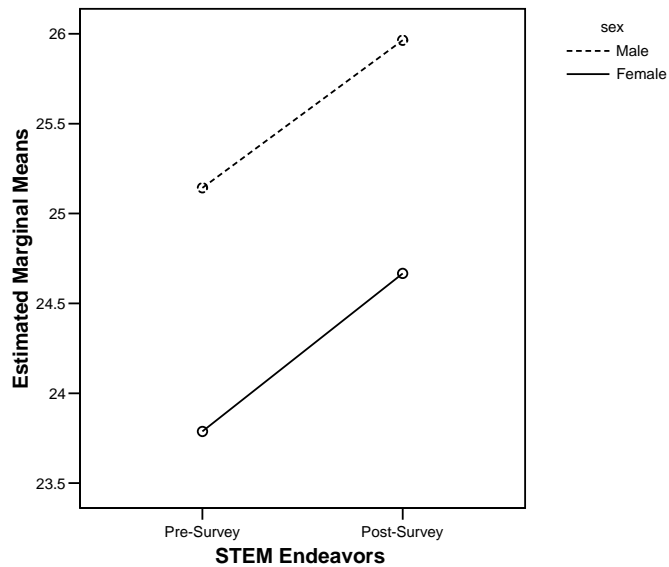


Figure 14: Changes in Attitudes Regarding STEM Endeavors (Experimental Girls versus Experimental Boys)

Control Group

The girls in the control group displayed a decrease in attitudes pertaining to Intended STEM endeavors, while the boys in the control group displayed an increase in intended STEM endeavors (See Table 10 for means and standard deviations). Figure 15 shows the changes in control girls' and control boys' attitudes over time for intended STEM endeavors.

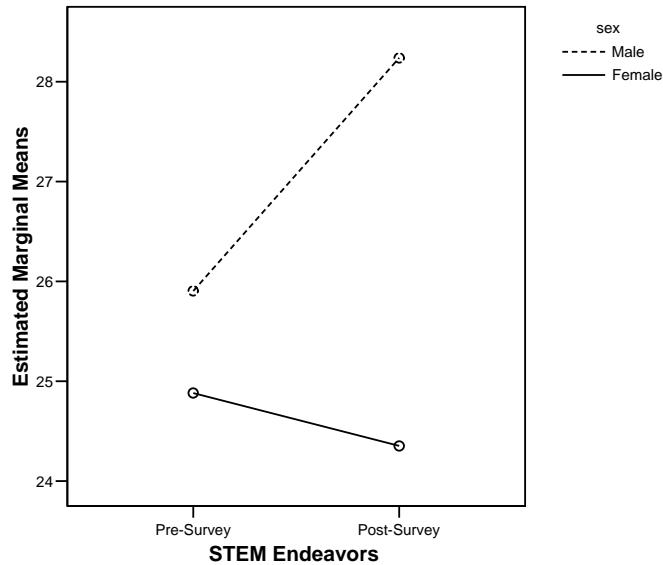


Figure 15: Changes in Attitudes Regarding STEM Endeavors (Control Girls versus Control Boys)

Mauchly's test of sphericity was not significant and sphericity, therefore, could be assumed. Although there was a difference in direction of change, the GLM repeated measures analysis indicated there was no statistically significant difference in attitudes pertaining to intended stem endeavors when the girls in the control group were compared to the boys in the control group $F(1,36) = 3.866, p = .057$.

Usefulness of Mathematics

The results of the pre- and post-surveys were compared using SPSS (2003) GLM repeated measures to determine if there were any statistically significant positive changes in

attitudes regarding perceived usefulness when girls and boys within each treatment group were compared.

Experimental Group

Both the girls and the boys in the project-based experimental group showed an increase in their attitudes pertaining to perceived usefulness of mathematics (See Table 10 above for means and standard deviations). Figure 16 shows the changes in experimental girls' and experimental boys' attitudes over time for perceived usefulness of mathematics.

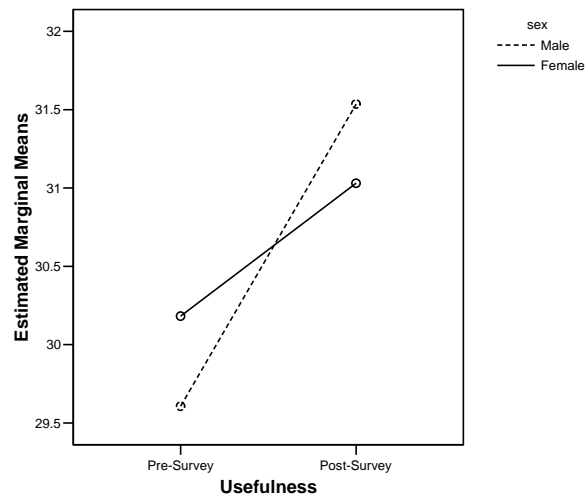


Figure 16: Changes in Attitudes Regarding Perceived Usefulness of Mathematics (Experimental Girls versus Experimental Boys)

Mauchly's test of sphericity was not significant and sphericity, therefore, could be assumed. The GLM repeated measures analysis indicated there was no statistically significant difference in

attitudes pertaining to intended perceived usefulness when the girls in the experimental group were compared to the boys in the experimental group $F(1,59) = 2.181, p > .145$.

Control Group

The girls in the control group displayed a decrease in attitudes pertaining to perceived usefulness of mathematics, while the boys in the control group displayed an increase in perceived usefulness (See Table 10 above for means and standard deviations). Figure 17 shows the changes in control girls' and control boys' attitudes over time for perceived usefulness.

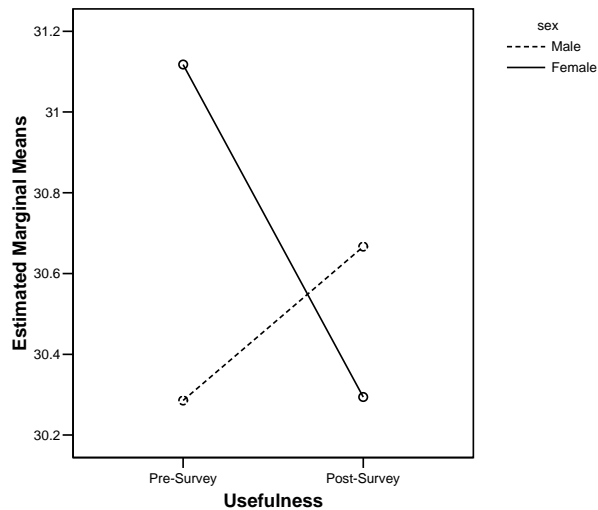


Figure 17: Changes in Attitudes Regarding Perceived Usefulness (Control Girls versus Control Boys)

Mauchly's test of sphericity was not significant and sphericity, therefore, could be assumed.

Although there was a difference in direction of change, the GLM repeated measures analysis

indicated there was no statistically significant difference in attitudes pertaining to perceived usefulness of mathematics when the girls in the control group were compared to the boys in the control group $F(1,36) = 1.127, p > .05$.

Perceived Competence

The results of the pre- and post-surveys were compared using SPSS (2003) GLM repeated measures to determine if there were any statistically significant positive changes in attitudes regarding perceived competence in doing mathematics when girls and boys within each treatment group were compared.

Experimental Group

Both the girls and the boys in the project-based experimental group showed a decrease in their attitudes pertaining to perceived competence in mathematics (See Table 10 above for means and standard deviations). Figure 18 shows the changes in experimental girls' and experimental boys' attitudes over time for perceived competence in mathematics. Mauchly's test of sphericity was not significant and sphericity, therefore, could be assumed. The GLM repeated measures analysis indicated there was no statistically significant difference in attitudes pertaining to intended perceived competence when the girls in the experimental group were compared to the boys in the experimental group $F(1,59) = .053, p > .05$.

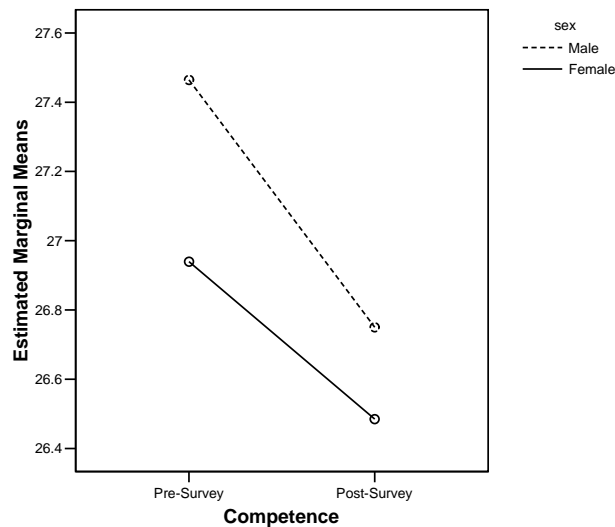


Figure 18: Changes in Attitudes Regarding Perceived Competence in Mathematics (Experimental Girls versus Experimental Boys)

Control Group

Both the girls and the boys in the control group displayed a decrease in attitudes pertaining to perceived competence in mathematics (See Table 10 above for means and standard deviations). Figure 19 shows the changes in control girls' and control boys' attitudes over time for perceived competence. Mauchly's test of sphericity was not significant and sphericity, therefore, could be assumed. Although there was a difference in direction of change, the GLM repeated measures analysis indicated there was no statistically significant difference in attitudes pertaining to perceived competence in mathematics when the girls in the control group were compared to the boys in the control group $F(1,36) = .522, p > .05$.

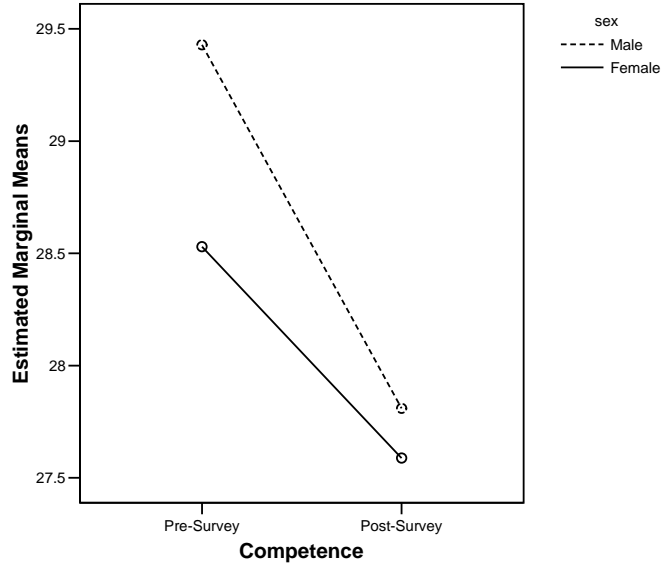


Figure 19: Changes in Attitudes Regarding Perceived Competence (Control Girls versus Control Boys)

Gender and Achievement

There were no significant differences (at the .05 level) when girls were compared between treatment groups and when boys were compared between treatment groups in terms of achievement. There were also no significant differences when girls and boys were compared within each treatment group. The means and standard deviations of the experimental and control groups broken down by gender are listed in Table 11.

Between Treatment Groups - Girls versus Girls and Boys versus Boys

The experimental girls' and control girls' semester examinations were compared using a t-test in order to determine if there were any differences in means. Levene's test for equality of variances indicated that equal variances could be assumed ($F=3.884, p>.05$). The experimental

girls ($M = 84.5$, $SD = 8.94$, $n = 33$) and the control girls ($M = 87.2$, $SD = 6.59$) showed no appreciable differences in achievement at the .05 significance level, $t(48) = 1.094$, $p = .279$ (See Table 11 for gender achievement data).

Table 11
Achievement Results from Semester Examinations by Gender

	Semester Examination	
Experimental Group	Mean	SD
Both ($n=61$)	85.2	8.82
Girls ($n=33$)	84.5	8.94
Boys ($n=28$)	86.0	8.76
Control Group	Mean	SD
Both ($n=38$)	86.5	7.47
Girls ($n=17$)	87.2	6.59
Boys ($n=21$)	85.9	8.23

The experimental boys' and control boys' semester examinations were also compared using a t-test in order to determine if there were any differences in means. Levene's test for equality of variances indicated that equal variances could be assumed ($F=.065$, $p>.05$). The experimental boys ($M = 86.0$, $SD = 8.76$, $n = 28$) and the control group boys ($M = 85.9$, $SD = 8.23$, $n=21$) also showed no appreciable differences in achievement at the .05 significance level,

$t(47) = -0.46, p = .964$. Achievement, therefore, did not seem to be affected by the particular treatment group the student belonged to.

Within Treatment Groups - Girls versus Boys

The experimental girls' and experimental boys' semester examinations were compared using a t-test in order to determine if there were any differences in means. Levene's test for equality of variances indicated that equal variances could be assumed ($F=.357, p>.05$). The experimental girls ($M = 84.5, SD = 8.94, n = 33$) and the experimental boys ($M = 86.0, SD = 8.76, n = 28$) showed no appreciable differences in achievement at the .05 significance level, $t(59) = 0.647, p = .520$ (See Table 11 for the gender achievement data).

The control girls' and control boys' semester examinations were also compared using a t-test in order to determine if there were any differences in means. Levene's test for equality of variances indicated that equal variances could be assumed ($F=.950, p>.05$). The control group girls ($M = 87.2, SD = 6.59$) and the control group boys ($M = 85.9, SD = 8.23$) also showed no appreciable differences in achievement at the .05 significance level, $t(36) = -0.541, p = .592$. The particular treatment group the student belonged to, therefore, did not affect achievement when gender was considered. The results indicate that there wasn't a particular advantage or disadvantage to girls or to boys in terms of achievement by belonging to a particular treatment group.

Qualitative Analysis

A qualitative analysis was undertaken in order to understand the process of project-based learning as experienced by the students. Qualitative research is used for exploring a topic in more

depth (Gay & Airasian, 2000). The qualitative analysis involved a phenomenological study of the participants' experiences in a project-based learning environment and was used in conjunction with the quantitative results for a better interpretation of the data.

It was anticipated that a project-based mathematics learning environment would increase the students' intended STEM endeavors, increase the students' perceived usefulness of mathematics, and increase the students' perceived competence in doing mathematics without undermining their academic achievement. The qualitative analysis sought to analyze, interpret, and understand the participants' experiences with the phenomenon of project-based learning.

Triangulation is a method used in qualitative research to ferret out common themes in the data (Gay & Airasian, 2000). Triangulation is used to find regularities in the data by crosschecking information across several different sources of data. The different sources of qualitative data used in this research study came from the student reflections, individual write-ups, group presentations, formal 5-minute interviews, and informal teacher-student conversations. When comparing data from multiple sources, an idea that arises in more than one of these sources validates the idea as a significant theme that the researcher should address.

The qualitative data were formally analyzed using the four-step process of re-reading, classifying, categorizing, and interpreting the data (Gay & Airasian, 2000). Students' experiences were gathered through formal and informal means. Formally, students were asked to comment on their experiences in the post-questionnaire through the specific question, "How have your experiences this year changed your intentions about majoring in science, technology, engineering, or mathematics in college or in taking science, technology, or mathematics courses in high school?" (See Appendix I for the Post-Questionnaire). The first formal step in the

triangulation process was to read through the responses to their post-questionnaire responses and list any common themes.

Students were also interviewed during each project in a formal 5-minute teacher-student interview. During this interview, students were mainly asked about their group dynamics, but project experiences were also discussed. The researcher, following each interview, wrote down the main ideas mentioned by the student. Later these ideas were analyzed and added to the list of ideas generated from the post-questionnaire response. Students also wrote reflections (See Appendix H) after each project and were asked to comment on aspects of project solutions, stumbling blocks, group dynamics, their presentations, and their overall project experience. Again the ideas generated from the reflections were added to the ever-growing list of ideas and concerns the students had in regard to their project-based learning experience. In the reflections, students were asked questions such as “Was it a worthwhile experience?”, “What did you learn?”, and “Did you find it interesting or boring?” Students were asked to explain their answers to these questions, and their responses provided valuable feedback as to their thinking processes and their experiences. Feedback was also gathered through the students’ group presentations and individual write-ups. Any significant concepts emerging from these two sources of information were also incorporated into the growing list. In the write-ups and presentations, students were required to discuss not only their solutions to the problem but also discuss any problems or stumbling blocks that occurred while working on their projects.

The teachers involved in the study formally consulted with each other on a regular basis in order to compare notes about progress of the project-based curriculum and also to compare notes about students’ experiences. Informally, both teachers continually talked with students about their experiences throughout the experiment during the natural teacher/student interactions

in class. Any concerns or significant ideas were added to the lists of important themes emerging from the qualitative analysis.

The students held the key to making the project-based learning experience effective for themselves and for discerning what effects, if any, were noteworthy. Once the sources of qualitative data were analyzed and the patterns emerged, the data were re-read in a holistic sense in order to discern if the initial meticulous process of idea gathering had missed any important themes. This laborious process was necessary in order to ensure that the students' ideas and concerns were fairly and accurately represented.

In addition to uncovering common themes from the qualitative data, three initial questions were kept in mind as the data were analyzed:

1. What experiences influenced students' intended STEM endeavors in mathematics?
2. What experiences influenced students' perceived usefulness of mathematics?
3. What experiences influenced students' perceived competence in doing mathematics?

The information that was gathered through both formal and informal means was examined in order to give insight into the questions posed above and to glean other common reactions or themes. In addition to the themes of STEM endeavors, perceived usefulness of mathematics, and perceived competence in mathematics, two additional major themes emerged from the qualitative data: the project-based process itself and content coverage.

Several themes emerged from the triangulation of the qualitative data and are discussed below.

STEM Endeavors

The theme of intended STEM endeavors was not a theme that emerged from the student qualitative data; it was a theme that was explored in order to determine the students' shared experiences. As the projects progressed, the students in the experimental group seemed to look forward to the projects. However, even though the students seemed to enjoy the projects and requested more of them, relatively few of the students considered changing their career plans, as shown by the quantitative analysis. The qualitative analysis showed similar results.

The qualitative analysis showed that only a handful of the 99 students discussed any type of intention to pursue a STEM endeavor through more STEM courses in high school, STEM college majors, or pursuing a STEM career. One example of a student's interest in STEM endeavors occurred during work on the airplane project (See Appendix D for a description of the Airplane Project). As students were gathering data during the second round of test-flights with their "improved" airplanes, one student, an 8th grade boy, made the following comment, "Wouldn't it be cool to actually do this with real airplanes?" When the teacher responded that many engineers did this exact thing, his eyes lit up as he considered this for the first time. The teacher, seeing his enthusiasm, continued with "You should check into aerospace engineering and see what that's all about." The student seemed very enthusiastic about the prospect and came back the very next day armed with a list of colleges that had aerospace engineering schools. Clearly, this particular project influenced this one student.

Another instance of STEM interest came from an eighth-grade girl who was also in the experimental group. She wrote in her bridge-project (See Appendix E for a description of the Bridge Project) reflection, "I enjoyed the engineering concepts about bridge design." Another eighth-grade girl also mentioned in her bridge-project reflection that she enjoyed "how we got to

be architects.” Another eighth-grade boy, this one in the experimental group, wrote in his post-questionnaire, “I have found that math is more fun than I thought and this encourages me to take more math courses.”

A handful of students in the control group also indicated an interest in STEM endeavors. An eighth-grade boy in the control group who had originally intended to pursue a career in science wrote, “I now know the exact type of science and math I am interested in. For instance, I plan to major in chemistry and possibly chemical engineering.” An eighth-grade girl in the control group wrote, “Ever since I was little I have wanted to be a surgeon and my experiences in learning math and science have only encouraged that even more. In college I want to learn even more math and science.” A seventh-grade girl in the control group wrote in her post-questionnaire, “I am more interested in math courses as well as science courses.” Only a handful of students in each of the experimental and control groups indicated an interest in STEM endeavors. This indicated that STEM endeavors did not seem influenced by treatment group membership.

This small sample of comments about STEM intentions indicated that most students held fast to their initial pre-treatment intended career goals. For instance, an eighth-grade girl in the experimental group, interested in sports as a career, wrote in her post-questionnaire, “I have never loved science or math, so I liked seeing what those jobs do but it is not my thing.” Another eighth-grade girl in the experimental group who aspires to be an actress echoed this sentiment. She wrote in her post-questionnaire, “Math class was very fun and I enjoyed it more than previous math classes. But math, science, and engineering are not the jobs I want to do in life.”

Perceived Usefulness of Mathematics

The usefulness of mathematics was a theme that did emerge from the qualitative analysis. The comments mentioning the usefulness of mathematics came from the students in the experimental group almost exclusively. For example, during a five-minute interview, an eighth-grade girl in the experimental group mentioned that it was fun to get out of the normal routine of the classroom. She said, “Learning math by doing book problems gets really boring sometimes, but going outside to do math was better.” When asked to elaborate she said that she realized that mathematics was useful in working out problems. She gave the bridge problem as an example. She said that she and her group were stumped at first when they had to come up with a method on their own for finding the distance across the canal. Her group had already grasped the fact that the teacher wasn’t going to supply them with a method for finding the solution. The student said that it was like a “flashbulb going off in my head” when she realized that they could set up a right triangle flat on the ground and use the tangent function to estimate the distance. She said to her teacher her accomplishment “might not seem so big to you, but it was huge to us.”

Another group of students, during their group presentation on the Florida aquifer, made it a point to come up with questions that could be solved using mathematics. The problems they came up with were challenging as well as informative. They asked the class “How long before the aquifer runs out if not replenished?” The group would not provide the students with information until asked. The presenters wanted the students to go through the same thought processes they had gone through to solve the problem of the aquifer running out. One student in the presenting group said during an informal post-presentation conversation with the teacher, “Somebody in our group wondered how long it would take for the aquifer to run out. We had to find out how many gallons of water the aquifer held, how much water was used everyday and

then do some calculations. It was kinda cool using math to solve a question we'd asked ourselves. We wanted the kids in the class to have the same experience so we held back the numbers on purpose."

An eighth-grade boy in the experimental group wrote, "This year I have realized that math is my strongest subject. It has reassured me that math is important for my future career." Another eighth-grade student, a girl in the experimental group, wrote, "My intentions [for taking more STEM courses] are basically the same. I realized, though, that math is more useful than I thought." Another eighth-grade student in the experimental group, a male who intends to become a writer, said "[My experiences this year] haven't really changed my intentions on majoring in science or math, but they have opened my mind to the fact that math can easily be applied in life." An eighth-grade girl wrote, "The projects are very different from regular math class and the concepts that they bring about really let you see how math is used in the real world and not just in textbooks."

Perceived Competence in Mathematics

The theme of perceived competence in doing mathematics was not a theme that emerged from the student qualitative data; it was a theme that was explored to determine the students' shared experiences concerning this theme. Although the students in the project-based curriculum understood that mathematics was useful in solving the problems, the projects did not seem to have any effect on their perceived competence in doing mathematics. An eighth-grade boy in the experimental group wrote in his post-questionnaire, "Well, this year in math has kind of been difficult for me because I have some trouble with the material. As a result, I feel less confident about taking those courses later on."

Many of the students did not seem to correlate the mathematics brought out by the projects as important. Their idea of mathematics seemed to remain one of book learning and pencil-and-paper testing. Whether they could do well on a written pencil-and-paper test seemed, to them, to be the true test of their competence in learning mathematics. For example, in a reflection, an eighth-grade boy wrote that although he enjoyed the projects, he was worried about the upcoming chapter test because some of the mathematics material had been learned from the projects. Right-triangle trigonometry was one such topic. Since right-triangle trigonometry was not in the particular chapter the class was studying at the moment but would be included on the next chapter test, he felt that the extra mathematics topic did not fit in with the rest of the material in the chapter. This was confusing for him, and he felt might handicap him for the test.

The Project-based Process

A qualitative analysis seeks to uncover common themes and reactions from participants. One of the emergent themes, one the researcher had not originally sought to explore, seemed to be the project-based process itself. Students mentioned their unfamiliarity with working independently without the teacher's direct guidance and a ready algorithm. The students, it seems, have been so ingrained with textbook problems that they were uncomfortable, initially, doing problems without the comfort of knowing and applying a ready-made algorithm. Another issue related to the project-based process was the problems associated with group dynamics. Students had some measure of difficulty when assigned to groups in which they had to work with students they had never worked with before. Another oft-mentioned aspect of the problem-based process was the change of pace. Students seemed to be overwhelmingly in agreement that they enjoyed the change of pace from the lecture-based format.

Independence

In the beginning of the project-implementation process, many students asked their teachers for help on a regular basis. The students, it seemed, were not used to working on their own without direct teacher intervention. During the first project, a few groups made statements such as “We don’t know what to do” and asked general questions such as “How do we start?”. Other groups, on the other hand, asked more specific questions such as “Can we climb the flagpole?”. The students, it seemed, were at different levels in terms of their abilities to work independently.

Although all of the students seemed to enjoy the projects, some of the students were clearly out of their comfort zone. Some of the students who excel in teacher-driven, lecture-based instruction had to make adjustments to the more open-ended project-based instruction. Several groups struggled when left to their own devices. An eighth-grade boy in the experimental group said, “Finding the distance across the canal was our only problem. We had trouble coming up with a method.” Another student wanted to know if the teacher was going to reveal the one correct method for finding the distance across the pond. The student asked, “Are you going to tell us the right way to find the distance across the canal?” The student was not satisfied when the teacher answered that there was no one “right” way to find the distance across, and that there might be several solution methods. This same student became even more flustered when she asked whether the teacher would reveal the true distance across the canal. The teacher had responded that she didn’t know the actual distance across the canal. An eighth-grade boy echoed this frustration by writing, “I would like it better if [the teacher] could tell us if we came close to finding the width of the canal.”

As the students became more familiar with the problem-solving process and the teacher's role as "guide on the side" they became much more self-assured and able to work on their own. For example, an eighth-grade girl in the experimental group, referring to the calculations required for the five-number summary for a box-and-whisker plot, asked her teacher, "I know you won't tell me the answer, but am I at least doing this right?"

Once students became more familiar with the project-based method, they worked out problems and pursued research on their own in much more depth than either of the teachers in the study anticipated. This sort of sticking with a problem is rarely seen in mathematics classes. For instance, several groups tried a couple of different techniques for solving the height of the flagpole. Groups used trigonometry by setting up a right triangle with the flagpole as one leg and the shadow as the other leg. Several groups then checked their results by setting up similar triangles. One triangle consisted of the flagpole and its shadow while the other triangle consisted of a student and the student's shadow. One group totally surprised the teachers by coming up with a unique method of solution. The students took a Polaroid photograph of a student standing next to the flagpole. Using the student's height they used the idea of scale factor and proportions to compute the height of the flagpole.

The point here is that the students stayed with the problem longer than if the problem had been a textbook problem. Schoenfeld (1985) wrote this in reference to lecture-based mathematics instruction - "a 10-minute 'problem' was truly extraordinary. Students were never given the impression that one might spend hours (much less days, weeks, or months) working a problem. Rather, the impression was that subject matter in mathematics could be mastered in bite-sized chunks" (p.369). Clearly, the students in the project-based group learned first hand that problems can take more than a few minutes to solve.

Groups Dynamics

Another emergent issue within the problem-based process was that of group dynamics. Students self-selected their groups of four or five members for the very first project – the flagpole project. Interestingly, none of these self-selected groups consisted of all males or all females. There didn't seem to be any particular problems with group dynamics in this scenario since the students seemed to get along well with their group mates. Their 5-minute interviews reflected this. For example, an eighth-grade girl in the experimental group said, "We're working together fine. We divided up the work and everybody got an equal amount. At first I didn't get enough to do so we rearranged everything." Another eighth-grade girl, in a different group commented, "My group got along well. If we did not agree on something we discussed it, and then came up with an answer."

After the initial project, students were randomly placed in groups of four or five. The thought behind this was that when students work in groups they learn how to work collaboratively and effectively with others towards a common goal (Milner-Bolotin, 2001). Rottier and Ogan (1991) recommended that students be placed in different groups as the project changed. They rationalized that students need to learn to work with many different types of people. None of the groups, as it turned out, consisted of all females or all males. The difficulties in group dynamics began to arise when students were randomly placed into project groups. Several power struggles ensued. One eighth-grade girl wrote in her bridge project reflection, "We tried to work through our disagreements to find the bridge and method that worked. I was outnumbered by the group so I didn't really have a say about what we did." Another eighth-grade girl in different group wrote in her bridge-project reflection, "We had trouble finding the

right scale for our scale drawing because as soon as we agreed on something someone else had a different idea and we'd start over. It got really frustrating.”

In one of the project reflections, an eighth-grade boy, when asked what he would like to see change about the project, strongly recommended, “Let us choose our groups!” Another eighth-grade member of a bridge project group complained “Two of our group members were always against each other.” Clearly several groups experienced power struggles and discomfort working with other students. The teachers of these dysfunctional groups encouraged diplomacy and compromise. One eighth-grade girl commented “There were some small conflicts about involvement that were quickly solved.” The students quickly discovered that not only were there mathematical problems to be solved but also problems with group dynamics as well.

Change of Pace

Another emergent theme concerning the project-based process that students in the experimental group brought up was that they liked the change of pace and change of routine of the mathematics class. When asked what he enjoyed about the very first project, an eighth-grade boy wrote in his reflection, “It was more hands-on and also more fun.” Another student, an eighth-grade girl, similarly wrote, “The projects are more hands-on and not all class work.” An eighth-grade girl said, “It was fun to be outside during math class. It's better than regular math class!” This particular sentiment was echoed by many of the students.

The students seemed to enjoy the fun and creative atmosphere of the class. A seventh-grade girl said, “It was fun and we got to be creative with our designs.” Others enjoyed the role-playing aspect. “We enjoyed being architects,” an eighth-grade boy wrote in a reflection after the

bridge project. Another eighth-grade boy said he enjoyed “pretending like I was an engineer. I liked having the freedom to decide what bridge to use and what scale to pick.”

Content Coverage

One of the concerns with a project-based approach to mathematics instruction was content coverage. Apparently, content coverage was not only a concern for the teachers since several students also seemed concerned with this aspect of the course. The algebra content as it was covered by both the control group and the treatment group is listed in Table 12. The problem-based treatment group is also broken down into what content was covered through the lecture-based method and what content was covered through the problem-based method.

Both teachers commented that there was plenty of time for content coverage within the project-based classes. The teachers were able to cover the same content in both groups through various means. For instance, the project-based group studied proportions and similar figures through the flagpole project during weeks 1 and 2 and thus didn't have to cover the topic when the control group did in weeks 3, 4, and 5. This type of content coverage also occurred with right triangle trigonometry. The project-based group studied right triangle trigonometry during both the flagpole and bridge projects and didn't need to recover the material in weeks 14 through 17 when the control group did. In fact, one of the teachers commented that the beauty of the project-method was that since the students learned right-triangle trigonometry so early in the year that it would be not be necessary to reteach the topic later in the semester. There was always a bit of uncertainty as to what content the students would use to solve their problems, but as one of the teachers said, “I just went with the flow and the students came through.”

Table 12
Schedule of Algebra Course Content Covered

Semester 1 Week #	Control Group	Experimental Group Algebra Content	
		Lecture-Based Content	Project-Based Content
1 & 2	Order of operations, Algebraic properties (e.g. Commutative, Associative, Distributive) Descriptive statistics	Same topics.	<u>Flagpole Project:</u> Similar figures (triangles), proportions, right-triangle trigonometry
3, 4, & 5	Rates, Ratios, Proportions, Scale factor, Similar figures, Solving and graphing linear equations	Rates, Ratios, Solving Linear Equations only	<u>Paper Airplanes:</u> Descriptive statistics including measures of central tendency (median, mean), measures of spread (interquartile range, standard deviation), graphical depictions of data (comparative boxplots), and $D=RT$
6,7,8, & 9	Solving and graphing linear inequalities, Powers and exponents	Same but also included Graphing linear equations	<u>Bridge Project.</u> Similar figures (triangles), proportions, right-triangle trigonometry, Law of Sines, scale factor, proportions
10,11,12, & 13	Probability, Radicals, Number sets, Adding polynomials, Multiplying polynomials	Same topics except for Multiplying polynomials	<u>Ecology Project.</u> Volume, bar graphs, solving linear equations, graphing linear equations, proportions, scale factor
14, 15, 16, & 17	Right triangle trigonometry, Function notation, Domain and range, Rational exponents	Same topics but include Multiplying polynomials and exclude Right triangle trigonometry	

The control group was often given time in class to work on homework assignments, but this was not always the case for the project-based group. The project-based group would often go back to working on their projects after the lecture-based mathematics portion of the class and the students did not have time in class to work on textbook assignments. Another method used to ensure similar content coverage was that the control group would receive a day in class to do test corrections while the project group would either not be required to do test corrections or would be expected to do them at home. Neither teacher felt hurried or rushed to finish the content in either of the treatment groups.

Another interesting aspect of content emerging from the projects was when students hit on a topic that was typically covered either in the second semester of the course or was covered in another course altogether. Again, this wasn't a problem for either teacher and the students simply learned this content ahead of schedule. One example to illustrate this point came when an experimental group attempted to find the distance across the canal in the bridge project. The group set up an obtuse triangle and subsequently needed to use the Law of Sines to calculate the distance. The Law of Sines is not typically taught in an algebra class, but again, the teacher "went with the flow" and taught this particular group the Law of Sines. That group, in turn, taught the Law of Sines to the rest of the class.

Students in the project-based experimental group seemed continually concerned about the pace of their class when compared to the control group. Students in the project-based group continually asked questions such as, "How far ahead of us are they [the control group]?" Students seemed to measure their progress in terms of pages and sections in the textbook. Students also asked questions such as "Are we going to have the same semester exam?" When reassured that both groups would cover the same content during the semester, students seemed

skeptical. “They’re so far ahead – how can we catch up?” Students seemed to relax more when they finally understood that some of the content they had learn during the projects (trigonometry, similar triangles, proportions, and box-and-whisker plots, for example) had not yet been covered by the control group. They seemed to understand and relax more as the semester progressed.

Qualitative Analysis Summary

The researcher formed a much better understanding of what it was like to have experienced a project-based method of learning after analyzing the qualitative data. Three main themes emerged as a result of this qualitative analysis: Usefulness of mathematics, the project-based process, and content coverage.

The usefulness of mathematics was brought up often by students in the experimental group, but rarely by the students in the control group. The students in the experimental group mentioned that they realized how mathematics could be used for solving real-world problems. Students also mentioned that they enjoyed the role-playing. They enjoyed acting as civil engineers or architects and that they understood better the role that mathematics played in the sciences and engineering.

Students in the experimental group mentioned many things about the project-based process itself. They mentioned the difficulties and frustrations they experienced from being on their own without the direct guidance of their teacher. They also mentioned that difficulties often arose when they were placed in groups with students they had never worked with before. Students also mentioned, quite enthusiastically, that they enjoyed the change of pace of the class and that mathematics class was more fun with the change of routine.

Students were also concerned about content coverage. As the students in the experimental group realized that the students in the control group were proceeding more quickly through the textbook, they seemed to become concerned that they were not getting the same content. They worried that they would not be prepared for their algebra semester examinations. The students in the experimental group relaxed more when they realized that they had been learning topics well before the control group had learned them. It turned out that the same content was indeed covered in both the experimental classes and the control group classes.

CHAPTER 5

DISCUSSION AND IMPLICATIONS

A search of the literature revealed that there are shortages in professional science, technology, engineering, and mathematics (STEM) participation. Both women's and men's domestic participation in STEM endeavors is reaching a critically low level, while the percentage of foreign-born professionals is steadily increasing (NSF, 2002).

The primary purpose of this study was to determine if a problem-based instructional setting within a mathematics class would significantly influence students' intentions to pursue STEM endeavors. Secondary to this initial intent was to determine if a project-based learning environment would influence students' perceptions about the usefulness of mathematics and their perceptions about their own competence in doing mathematics.

The project-based mathematics curriculum implemented in the study was an attempt to model actual engineering and science scenarios in which students were presented with a problem and had to actually *do* engineering and science. The key to the project-based curriculum was to allow students to find their own solutions without much teacher intervention and without simply applying the current mathematical procedure being taught in class. Schoenfeld (1985) made the following distinction between problem and exercise: "If one has ready access to a solution schema for a mathematical task, that task is an exercise and not a problem" (p. 74). A problem, he said, is one for which students do not have an immediate solution and must search their internal databanks for potential solutions.

Noted educators John Dewey and William Kilpatrick were proponents for experiential learning. Dewey (1900) said, "there is very little place in the traditional schoolroom for the child to work" (p. 32). He envisioned that school would be a place "in which the child may construct,

create, and actively inquire” (p. 32). Kilpatrick (1926) said, “We learn better – certainly as a rule – when we face a situation calling for the use of the thing to be learned” (p. 357). Both Dewey (1900, 1916) and Kilpatrick (1918) insisted that the purpose of education was not only to prepare students for life after school but also to help students in the present participate as full-fledged members of society.

McIlwee and Robinson (1992) found that most of the professional women engineers in their study did not have much experiential learning. These women had little hands-on experience tinkering with mechanical devices before they entered the engineering field. The professional men engineers, however, indicated that they did have a strong orientation towards hands-on tinkering with mechanical devices. The project-based method in this research study was designed to bring some hands-on activities to the students in order for them to experience the power of discovering solutions to problems on their own.

Results

The research results indicated that there was a statistically significant difference between students in the experimental group and students in the control group in terms of perceived usefulness. The control group showed a decrease in perceived usefulness while the experimental group showed an increase. Although both the control and experimental groups increased their intentions to pursue STEM endeavors, neither group increased significantly over the other. The perceived competence of both treatment groups decreased, but neither group showed a more significant decrease than the other. The academic achievement of both groups remained relatively close and again there was no significant difference between the experimental and control groups.

The qualitative analysis of the data uncovered several themes from the students' reported experiences in the project-based learning environment. The three main themes that emerged as a result of this qualitative analysis included the usefulness of mathematics, aspects of the project-based process itself, and content coverage.

Usefulness

The results of this research study indicate that students who received the project-based mathematics instruction showed a statistically significant increase in their perceived usefulness of mathematics ($p < .05$). The GLM repeated measures analysis indicated there was a statistically significant increase in attitudes pertaining to perceived usefulness when the experimental (project-based) group was compared to the control group $F(1, 97) = 5.14, p = .022$. Many researchers (Meyer & Koehler, 1990; Armstrong, 1985; Armstrong & Price, 1982; Pedro, Wooleat, Fennema, & Becker, 1981; Lantz & Smith, 1981) found that perceived usefulness was a major factor predicting whether middle- and high-school students pursued STEM endeavors. The effect size was small however (eta-squared = .053), perhaps due to the relatively short duration of the study or the bigger class sizes in the experimental group. The study ran for one semester, the first semester of the school year. Perhaps if the study had been run over a longer period of time, the entire year for example, the effect size may have been larger.

The NCTM (2000) in their influential publication *Principles and Standards for School Mathematics* called for the application of mathematics in mathematics instruction. These applications are often called word problems or story problems. In traditional lecture-based instruction these word problems are often merely exercises in Shoenfeld's (1985) sense of the definition. Students have solved countless numbers of exercises in the name of problem solving

by working exercises using the mathematical algorithm they had been currently using in the classroom. The problem-based environment in this research study, on the other hand, forced students to solve problems out of context. Students had to pull from their own store of knowledge to solve the problems. It is from this self-exploration that students came to realize that mathematics has more uses than simply answering questions on a mathematics chapter test. The students came to realize that mathematics could be used in many places for many things. One eighth-grade girl in the experimental group wrote in a reflection, “We hadn’t learned similar triangles this year, but our group used that to find the height of the flagpole. We felt weird using it [similar triangles] when we hadn’t gone over it in class yet. But we figured that math is math and can be used whenever you need it.”

In the qualitative analysis students mentioned that they enjoyed the role-playing aspect of problem-based learning. They reported that they enjoyed acting as engineers and architects and they understood better the role that mathematics played in the sciences and engineering.

Gender Issues

Between Treatment Groups – Girls versus Girls and Boys versus Boys

The GLM repeated measures analysis in SPSS version 12 (SPSS, 2003) was used to determine if there were any statistically significant increases in attitudes in terms of any of the three constructs: intended STEM endeavors, perceived usefulness of mathematics, and perceived competence in mathematics when girls in the experimental group were compared with girls in the control group. There were no statistically significant increases in attitudes of the girls in the experimental (project-based) group when compared to the girls in the control. Interestingly, the girls in the experimental group evidenced positive changes in attitude regarding both intended

STEM endeavors and perceived usefulness of mathematics while the control group of girls showed decreases. Both groups of girls showed decreases in terms of their perceived competence in doing mathematics.

The same statistical analysis was done to compare the boys in the experimental group to the boys in the control group and again, there was no statistically significant increase in attitudes. The boys in both the experimental group and the control evidenced positive increases in both the perceived usefulness and intended STEM endeavors constructs, but both groups of boys evidenced decreases in their perceived competence.

Within Treatment Groups – Girls versus Boys

The GLM repeated measures analysis in SPSS version 12 (SPSS, 2003) was used to determine if there were any statistically significant increases in attitudes in terms of any of the three constructs: intended STEM endeavors, perceived usefulness of mathematics, and perceived competence in mathematics when girls were compared with boys within the same treatment group. There were no statistically significant differences between the girls in the experimental group when compared to the boys in the experimental group in terms of each of the three constructs. Both girls and boys in the experimental group showed increases in their attitudes in intended STEM endeavors and perceived usefulness of mathematics. However, both girls and boys in the experimental group showed decreases in attitude in terms of their perceived competence in doing mathematics.

There were no statistically significant differences between the girls in the control group when compared to the boys in the control group in terms of each of the three constructs.

Interestingly, the girls in the control group showed decreases in attitude in terms of both STEM

endeavors and perceived usefulness while the boys showed increases. However, both girls and boys in the control group showed decreases in attitude in terms of their perceived competence in doing mathematics.

Project-based Process

An analysis of the qualitative data indicated that students in the experimental group were concerned with the project-based process itself. They mentioned their independence from the teacher, group dynamics, and the change of pace of the problem-based curriculum. Katz and Chard (1989) suggested that in a project-based learning environment, students should “be encouraged to rely on the database of their own personal experience” (p. 121), but clearly they were uncomfortable with this process. For instance, students mentioned the frustrations and difficulties they experienced without the direct guidance of their teacher. They also mentioned some difficulties that came up when they were placed randomly in groups with students they had never worked with before. Students also mentioned, quite enthusiastically, that they enjoyed the change of pace of the class and that mathematics class was more fun with the change of routine.

Content Coverage

The problem-based approach in the research study sought to teach content through both lecture-based instruction and project-based instruction in order to ensure that any content that was *not* brought out naturally by the projects would be “covered.” Katz and Chard (1989) asserted that one of the primary goals of project work is to help students acquire new knowledge.

The qualitative analysis revealed that students were concerned about content coverage. They were worried that they would not be prepared for their algebra semester examinations. The main reason that content coverage was a concern is that a project-based instruction method takes more time than traditional instruction. The teachers were afraid some of the content would have to be cut or condensed in order to provide students enough time to explore problems, come up with solutions, receive feedback, make revisions, and give presentations. This was not the case, though, and both teachers in the study covered the content quite effectively.

Teacher Collaboration

The teachers in the study met both formally and informally to discuss how implementation of the project-based curriculum was progressing. Both teachers frequently mentioned that they were pleased with the enthusiasm of the students in the project-based group. One of the teachers mentioned that this student enthusiasm was infectious and she really looked forward to those class days when the students would be working on their projects.

The two teachers also helped each other in terms of content. During the airplane project for example, the main mathematics used by the students was descriptive statistics. One of the teachers had a strong background in statistics and helped the other teacher who did not have as strong a background understand certain statistical concepts such as standard deviation. This statistics-knowledgeable teacher not only helped her own students broaden their horizons as far as statistics were concerned, but also helped the other teacher broaden her content knowledge of statistics. Without this collaboration, some of the students would have been limited by the teachers' content knowledge. Dewey (1916) said that teachers must guide students through their interactions with the material and consequently, the teacher "must have subject matter at his

fingers' ends” (Dewey, 1916, p. 183). Teachers are clearly limited by their own understanding of content, but through collaboration can help each other grow and learn.

Implications

The problem-based method of instruction, as implemented in this study, presented the students with four projects during the first semester. The students were asked to solve problems by coming up with viable solutions using their current mathematical knowledge in conjunction with any new mathematical concepts their teacher felt was necessary for the project group to progress. Students had to deal with the social issues of working with others towards a common goal. Their experience of working with others is vital to their current and future roles as members of society (Dewey 1900, 1916). Teachers, Dewey suggested, helped students best by providing guidance for their inquiries and explorations instead of providing lists of facts to memorize.

Usefulness

The results of this research study logically suggest that project-based learning is a method for helping students understand the usefulness of their studying of mathematics. Too often students fail to make connections between the mathematics they learn in school and its practical application. Problem-based learning tied in with lecture-based instruction was the method of mathematical instruction used in this study. This method was the means for helping students see the ties between the concepts presented in their mathematics textbooks and the actual applications of these concepts in solving problems. For example, several groups used the concept

of similar triangles and proportions to find a solution for the height of the flagpole in the first project.

This approach to mathematics study caused students to become more enthusiastic in class. Dewey (1900) wished for a school environment in which students could do their own “work” (p.32). The students in the project-groups discovered value in their project work, stayed with problems longer, and consequently took great pride in their work. The hope was that students would become more intrigued by the pursuit of mathematics once they saw how the theory they learned in class applied to solving real-world problems. The hope was that students would come to see that mathematics has a place in their lives not only in the here and now, but also in the future. The goal of this research study was to help students see the point in learning mathematics and its related pursuits in science and engineering. The results of this research indicated that a problem-based mathematics curriculum increased students’ sense of usefulness of mathematics and this increase may be able to attract students into STEM pursuits now and later on in their lives.

Content

The results from the semester examinations and the qualitative data indicate that a project-based mathematics curriculum is an effective method for content coverage. The students used content from the algebra curriculum to solve the problems. During the initial project, the flagpole project, the students used right-triangle trigonometry, similar triangles, and scale factor. These three topics are certainly part of most algebra curricula. The airplane project was an exercise in research and development and helped students learn a context for statistics. The students learned aviation vocabulary as well as methods for organizing data using descriptive

statistics such as histograms, box plots, stem-and-leaf diagrams, means, and medians. The students used scale factor and trigonometry during the bridge project. The fourth project, the ecology project, was much more open-ended and allowed the students to explore topics and mathematics on their own. The students posed their own questions and solved problems they themselves created. The mathematics varied from group to group, but each group made mathematical sense of the project in appropriate ways. Some groups used descriptive statistics to compare declining animal populations of endangered species or to compare rates of paper recycling. Others used rates and proportions to compare declining levels of water in the Florida aquifer. Through careful consideration of projects, a project-based curriculum can be designed to facilitate a mathematics program by bringing out required content in applications contexts.

Conclusions and Limitations

The application of the theoretical mathematics learned in the classroom to solving problems is a prime example of higher-order critical thinking (NCTM, 2000). The various problems and projects in this research study forced students to “make conjectures, experiment with various approaches to solving problems, construct mathematics arguments, and respond to others’ arguments” as encouraged by the NCTM (2000, p.18). As students discovered the relevance and usefulness of the mathematical work they were doing, it became *their* work (Dewey, 1900). This student reaction became clear through their enthusiasm during project work and their desire for more projects.

In their influential publication, *Principles and Standards for School Mathematics* (NCTM, 2000), the National Council of Teachers of Mathematics encouraged mathematics educators to find methods and means for increasing the quantitative literacy in mathematics

students. Communication was one of several standards suggested by the NCTM (2000). “When students are challenged to think and reason about mathematics and to communicate the results of their thinking to others orally or in writing, they learn to be clear and convincing” (NCTM, 2000, p. 60). Students in the experimental problem-based group demonstrated their quantitative literacy by communicating intelligently in a mathematical environment. They communicated mathematically to each other within groups as they solved problems and then “spoke” mathematics during their presentations. Their use of mathematics and their ability to convey quantitative meaning was a testament to the problem-based learning environment.

Implementing a Project-based Curriculum

The hope of this researcher is that more teachers will consider using the project-based method in order to attract more students into mathematics or keep students in a high level of mathematics participation. The results of this research study indicated that students significantly increased their perceptions of the usefulness of mathematics while becoming more enthusiastic about its pursuit. Cautions go with this hope, however. Pursuing projects takes more classroom time. If the projects are carefully chosen and effort is taken to ensure that that the projects chosen can be solved with the required curriculum content then the rewards are worth the cost in time.

Projects selected for a problem-based learning environment should certainly be chosen on the merit that they contribute to the students’ progress in mathematics, but should also be selected on the merit that students find the projects interesting and relevant to their lives.

Dearden (1984, p.155) suggested that relevance was an important aspect of picking projects and suggested the following criteria:

1. Projects should be immediately applicable to students’ lives.

2. The topic should contribute to a balanced school curriculum.
3. The topic should have value in preparing students for life.
4. The project should have advantages to be gained from a study of the topic in school rather than elsewhere.

Henry (1994) also gave some practical suggestions for teachers interested in implementing a project-based curriculum. She pointed out that “It would be more valuable to pursue fewer projects in greater depth” (p. 144). She suggested that teachers outline what students will gain from doing a particular project. During this phase it would be imperative to discern what type of mathematics could potentially emerge from the projects. She also suggested that teachers develop ground rules with students for group work. She suggested that teachers help students understand the need for respecting others, allowing others to speak, ensuring that everyone has participated, and providing constructive feedback.

The goal of school mathematics is to help students understand that they are acquiring mathematical skills in order to solve problems (NCTM, 2000) as opposed to learning mathematical algorithms for their own sake. The strength of a project-based instructional approach is that students get the “big picture” (Hmelo, 1998, p. 203).

The projects in this study brought out the curiosity and problem-solving skills of the students in the experimental group. “In everyday life and in the workplace, being a good problem solver can lead to great advantages” (NCTM, 2000, p. 52). Students are a valuable resource and teachers must continue to identify those students who have a knack for problem solving. The ability to apply content, not just in a mathematics course, will help students solve the problems in their own lives, and will help them solve problems on a grander scale.

Limitations of the Study

The results of this study indicated that students in the experimental project-based group statistically significantly increased their sense of perceived usefulness of mathematics. The small effect size, perhaps due to the reliability of the homegrown measuring instruments, indicated that the results of the study might have limited scope. Perhaps the relatively short period of time allotted for the study (one semester) and/or the fact that the average experimental groups' class size was bigger overall than the control groups' average class size thwarted the influence the project-based learning environment had on the students.

The results of this study relied heavily on the quality of projects selected. Attempts to replicate this study may yield different results depending on the quality and quantity of projects chosen. The projects selected in this study were chosen purposefully in an attempt to influence the students to find solution methods that required content from the algebra curriculum.

The relatively small sample (N=99) of participants chosen for this particular study were students attending a private, primarily white, college preparatory school in the Central Florida area. These students usually take four years of high school mathematics and three to four years of high school sciences. Consequently, the students' interest in attending college and taking more math and science courses was already high to begin with and may have influenced the results of the study. Different results may occur in populations with differing demographics.

Suggestions for Further Research

A natural research question arises from the limitations suggested in the study. A more diligent look into the particular curriculum content brought out by the projects is certainly in

order. Field testing potential problems and discovering what actual mathematics the students actually draw out is important in order to help teachers who wish to implement a project-based curriculum stay on track with their curriculum content requirements.

Research using populations of different demographics would also be an excellent idea. A more careful look at the effects of a project-based mathematics curriculum on younger students, particularly elementary-school aged students, could potentially shed more light on the effectiveness of a project-based curriculum on students' interests in mathematics and science. Perhaps engaging students at a younger age will garner more significant results in terms of students' intended future STEM endeavors.

In their study of female and male engineers, McIlwee and Robinson (1992) found that the study of mathematics was a way for people to move out of low-paying jobs into STEM jobs that earned more status and respect. Perhaps studies can be attempted to explore whether a problem-based mathematics curriculum can help identify students with strong problem-solving skills and give them early potential career paths.

Finally, research involving problem-based learning would benefit from a longer time period of study. An entire school year, rather than the semester allotted in this study, would perhaps enable a researcher to better discern more practically significant results. A study involving an entire middle-school mathematics curriculum centered around project-based learning may be one such study. A longitudinal study of students involved in problem-based learning environments would also help researchers understand the long-term effects of a problem-based curriculum.

APPENDIX A
LETTERS OF INFORMED CONSENT

August 1, 2003

Dear Parent/Guardian:

I am a graduate student at the University of Central Florida pursuing my doctoral degree in Education under the supervision of faculty member, Dr. Juli Dixon, and I am conducting research on project-based learning in mathematics classes. The purpose of this study is to compare the students' interest in mathematics, science, technology, and engineering before and then after participating in the project-based environment. The study will take place during the fall semester.

The basic premise behind project-based learning is the idea that if students apply their mathematical knowledge to real-world problems and situations they will

- 1) perceive the usefulness of mathematics and come to value its pursuit.
- 2) become more confident in their own abilities to "do" mathematics.
- 3) stay interested in the pursuit of science, technology, engineering, or mathematics throughout their years in upper school, college, and beyond.

The results of the study may help Trinity Prep teachers get a better understanding of how to help students answer for themselves the question "When am I ever going to have to use this?" These results could directly benefit your child today as well as benefit future students.

This research is my effort to continue to improve the already excellent math program at Trinity Prep. Half of the participating students (the control group) will receive the excellent traditional instruction that the participating veteran teachers have used successfully at Trinity Prep for many years, while the other group (the experimental group) will also receive this traditional instruction, and will also participate in project-based learning. During the project-phase, the experimental group will participate in 5 projects. The first four projects will be teacher selected and are as follows: 1. Estimate the height of the flagpole on campus 2. Design a bridge over the canal on campus. 3. Design a paper airplane and improve on its design. 4. Design an ecology project such as the effects of recycling. The final project will be student derived. Students will work in groups on all projects.

Prior to the project-based instruction, students will take a pre-survey that asks them questions about their perceived competence in mathematics; perceived usefulness of mathematics; perceived appropriateness of women and men in science, technology, engineering, and mathematics endeavors; and their future plans pertaining to science, technology, mathematics, and engineering. The pre-survey will also ask personal information such as grade, sex, and parents' occupations. After the project-phase, students will take a post-survey that asks them the same questions found on the pre-survey with the addition of an open-ended question about their views of the project-method and their participation in it. I also plan to interview several students about their experiences while participating in the study. The students will not be asked to write their names on the questionnaires, but instead will be given a coded questionnaire

for matching purposes; their identities will be kept confidential to the extent provided by law. Semester exam results from the control group and the experimental groups will be compared to see if project-based instruction had any influence on achievement. Results will only be reported in the form of group data. Participation or nonparticipation in this study will not affect the students' grades or placement in any programs.

You and your child have the right to withdraw consent for your child's participation at any time without consequence. There are no known risks or immediate benefits to the participants. No compensation is offered for participation. Group results of this study will be available in May, 2004. If you have any questions about this research project, please contact me at (407) 671-4140 x409 or my faculty supervisor, Dr. Juli Dixon, at (407) 823-4140. Questions or concerns about research participants' rights may be directed to the UCFIRB office, University of Central Florida Office of Research, Orlando Tech Center, 12443 Research Parkway, Suite 207, Orlando, FL 32826. The hours of operation are 8:00 am until 5:00 pm, Monday through Friday except on University of Central Florida official holidays. The phone number is (407) 823-2901.

Please fill-out, sign, and return the attached permission slip. Thank-you for helping me in my research study.

Sincerely,

Barbara L. Clanton

July 1, 2003

Dear Mr. Maughan:

As you know, I am a graduate student at the University of Central Florida pursuing my doctoral degree in Education under the supervision of faculty member, Dr. Juli Dixon, and I am conducting research on project-based learning in mathematics classes. The purpose of this study is to compare the students' interest in mathematics, science, technology, and engineering before and after participating in a project-based environment. The study will take place in the fall semester.

The basic premise behind project-based learning is the idea that if students apply their mathematical knowledge to real-world problems and situations they will

- 1) perceive the usefulness of mathematics and come to value its pursuit.
- 2) become more confident in their own abilities to "do" mathematics.
- 3) stay interested in the pursuit of science, technology, engineering, or mathematics throughout their years in upper school, college, and beyond.

The results of the study may help Trinity Prep teachers get a better understanding of how to help students answer for themselves the question "When am I ever going to have to use this?" These results could directly benefit the students in the study immediately as well as benefit future students.

This research is my effort to continue to improve the already excellent math program at Trinity Prep. Half of the participating students (control group) will receive regular traditional instruction that the participating veteran teachers, Ms. Clanton and Mrs. Wilbur, have used successfully at Trinity Prep for many years, while the other group (experimental group) not only receives this traditional instruction, but also participates in project-based learning. During the project-phase, the experimental group will participate in 5 projects. The first four projects will be teacher selected and are as follows: 1. Estimate the height of the flagpole on campus 2. Design a bridge over the canal on campus. 3. Design a paper airplane and improve on its design. 4. Design an ecology project such as the effects of recycling. The final project will be student derived. Students will work in groups on all projects.

Prior to the project-based instruction, students will take a pre-survey that asks them questions about their perceived competence in mathematics; perceived usefulness of mathematics; perceived appropriateness of women and men in science, technology, engineering, and mathematics endeavors; and their future plans pertaining to science, technology, mathematics course, and engineering. The pre-survey will also ask personal information such as grade, sex, and parents' occupations. After the project-phase, students will take a post-survey that asks them the same questions found on the pre-survey with the addition of an open-ended question about their views of the project-method and their participation in it. I also plan to interview several students about their experiences while participating in the study. The students

will not be asked to write their names on the questionnaires, but instead will be given a coded questionnaire for matching purposes; their identities will be kept confidential to the extent provided by law. Semester exam results from the control group and the experimental groups will be compared to see if project-based instruction had any influence on achievement. Results will only be reported in the form of group data. Participation or nonparticipation in this study will not affect the students' grades or placement in any programs. Results will only be reported in the form of group data. Participation or nonparticipation in this study will not affect the students' grades or placement in any programs.

Students have the right to withdraw at any time without consequence. There are no known risks or immediate benefits to the participants. No compensation is offered for participation. Group results of this study will be available in May, 2004. If you have any questions about this research project, please contact me at (407) 671-4140 x409 or my faculty supervisor, Dr. Juli Dixon, at (407) 823-4140. Questions or concerns about research participants' rights may be directed to the UCFIRB office, University of Central Florida Office of Research, Orlando Tech Center, 12443 Research Parkway, Suite 207, Orlando, FL 32826. The hours of operation are 8:00 am until 5:00 pm, Monday through Friday except on University of Central Florida official holidays. The phone number is (407) 823-2901.

Please sign this letter granting me permission to conduct my research within Trinity Preparatory School. By signing this letter, you give me permission to contact the parents, students, and Mrs. Wilbur and ask for their informed consent to participate in this study. Thank you for your consideration.

Sincerely,

Barbara L. Clanton

_____ I have read the procedure described above.

_____ I grant permission to contact the students and teacher and ask for their informed consent to participate in this study.

_____/_____
Craig Maughan / Date
Headmaster, Trinity Preparatory School

July 1, 2003

Dear Teacher:

I am a graduate student at the University of Central Florida pursuing my doctoral degree in Education under the supervision of faculty member, Dr. Juli Dixon, and I am conducting research on project-based learning in mathematics classes. The purpose of this study is to compare the students' interest in mathematics, science, technology, and engineering before and then after participating in the project-based environment. The study will take place during the fall semester.

The basic premise behind project-based learning is the idea that if students apply their mathematical knowledge to real-world problems and situations they will

- 1) perceive the usefulness of mathematics and come to value its pursuit.
- 2) become more confident in their own abilities to "do" mathematics.
- 3) stay interested in the pursuit of science, technology, engineering, or mathematics throughout their years in upper school, college, and beyond.

The results of the study may help Trinity Prep teachers get a better understanding of how to help students answer the question "When are we ever going to have to use this?" These results could directly benefit the students in the study immediately as well as benefit future students.

This research is my effort to continue to improve the already excellent math program at Trinity Prep. Half of the participating students (control group) will receive regular traditional instruction that the participating veteran teachers have used successfully at Trinity Prep for many years, while the other group (experimental group) not only receives this traditional instruction, but will also participate in project-based learning. During the project-phase, the experimental group will participate in 5 projects. The first four projects will be teacher selected and are as follows: 1. Estimate the height of the flagpole on campus 2. Design a bridge over the canal on campus. 3. Design a paper airplane and improve on its design. 4. Design an ecology project such as the effects of recycling. The final project will be student derived. Students will work in groups on all projects.

Prior to the project-based instruction, students will take a pre-survey that asks them questions about their perceived competence in mathematics; perceived usefulness of mathematics; perceived appropriateness of women and men in science, technology, engineering, and mathematics endeavors; and their future plans pertaining to science, technology, mathematics course, and engineering. The pre-survey will also ask personal information such as grade, sex, and parents' occupations. After the project-phase, students will take a post-survey that asks them the same questions found on the pre-survey with the addition of an open-ended question about their views of the project-method and their participation in it. I also plan to interview several students about their experiences while participating in the study. The students will not be asked to write their names on the questionnaires, but instead will be given a coded

questionnaire for matching purposes; their identity will be kept confidential to the extent provided by law. Semester exam results from the control group and the experimental groups will be compared to see if project-based instruction had any influence on achievement. Results will only be reported in the form of group data. Participation or nonparticipation in this study will not affect the students' grades or placement in any programs. Results will only be reported in the form of group data. Participation or nonparticipation in this study will not affect the students' grades or placement in any programs.

Students have the right to withdraw from participation at any time without consequence. There are no known risks or immediate benefits to the participants. No compensation is offered for participation. Group results of this study will be available in May, 2004. If you have any questions about this research project, please contact me at (407) 671-4140 x409 or my faculty supervisor, Dr. Juli Dixon, at (407) 823-4140. Questions or concerns about research participants' rights may be directed to the UCFIRB office, University of Central Florida Office of Research, Orlando Tech Center, 12443 Research Parkway, Suite 207, Orlando, FL 32826. The hours of operation are 8:00 am until 5:00 pm, Monday through Friday except on University of Central Florida official holidays. The phone number is (407) 823-2901.

Please sign and return this letter. By signing this letter, you agree to participate as one of the teachers in the study. You also give me permission to report your responses in the final manuscript to my doctoral committee as part of my doctoral work. Thank you for your consideration.

Sincerely,

Barbara L. Clanton

_____ I have read the procedure described above.

_____ I voluntarily agree to participate in the procedure.

_____/_____
Teacher Signature / Date
Teacher, Trinity Preparatory School

APPENDIX B
PRE-QUESTIONNAIRE

Mathematics



**Pre-Questionnaire for
Middle School Students**

Please return your completed questionnaire to:

Barbara L. Clanton
Trinity Preparatory School
Winter Park, FL 32792

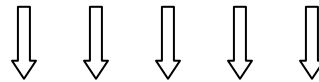
Please read each statement and indicate the extent to which you agree or disagree on a scale of 1 to 5, where 1 means you strongly disagree and 5 means you strongly agree.

Circle your responses.

1-Strongly Disagree	2-Somewhat Disagree	3-Neither Agree Nor Disagree	4-Somewhat Agree	5-Strongly Agree
---------------------	---------------------	------------------------------	------------------	------------------

START HERE

To what extent do you agree or disagree with the following statements?



- | | | | | |
|---|---|---|---|---|
| 1. The mathematics I learn in1 school is useful in everyday life. | 2 | 3 | 4 | 5 |
| 2. I will take more mathematics.....1 courses because they are useful. | 2 | 3 | 4 | 5 |
| 3. I feel confident that I will be.....1 able to learn the mathematics in the next chapter in my math class. | 2 | 3 | 4 | 5 |
| 4. I will be able to learn Calculus..... 1 | 2 | 3 | 4 | 5 |
| 5. I would consider majoring1 in mathematics in college. | 2 | 3 | 4 | 5 |
| 6. I plan to take more than one1 mathematics course in college. | 2 | 3 | 4 | 5 |
| 7. I would consider majoring.....1 in science in college. | 2 | 3 | 4 | 5 |
| 8. People who are not scientists.....1 or engineers use mathematics. | 2 | 3 | 4 | 5 |
| 9. My mathematics teachers think1 I am good at mathematics. | 2 | 3 | 4 | 5 |
| 10. I would consider majoring1 in computers/technology in college. | 2 | 3 | 4 | 5 |

1-Strongly Disagree	2-Somewhat Disagree	3-Neither Agree Nor Disagree	4-Somewhat Agree	5-Strongly Agree
---------------------	---------------------	------------------------------	------------------	------------------



- | | | | | | |
|--|---|---|---|---|---|
| 11. I plan on taking at least one AP mathematics course in upper school. | 1 | 2 | 3 | 4 | 5 |
| 12. I will use mathematics even after I graduate from college. | 1 | 2 | 3 | 4 | 5 |
| 13. Mathematics is one of my best subjects. | 1 | 2 | 3 | 4 | 5 |
| 14. I do mathematics problems fairly easily. | 1 | 2 | 3 | 4 | 5 |
| 15. I use mathematics in my everyday life. | 1 | 2 | 3 | 4 | 5 |
| 16. My parents use mathematics in their lives. | 1 | 2 | 3 | 4 | 5 |
| 17. I am able to do the MathCounts problems-of the week successfully. | 1 | 2 | 3 | 4 | 5 |
| 18. Mathematics will be useful in my future career. | 1 | 2 | 3 | 4 | 5 |
| 19. I would consider majoring in engineering in college. | 1 | 2 | 3 | 4 | 5 |
| 20. I am good at mathematics. | 1 | 2 | 3 | 4 | 5 |

Indicate answers for 21-22 by marking the box with an **X**.

21. What grade are you in?

6th

7th

8th

22. What is your sex?

Female

Male

Indicate answers for 23-25 by marking each box that applies with an **X**.

23. What mathematics courses do you plan to take in high school?

Geometry/Honors Geometry

Algebra 2/Honors Algebra 2

PreCalculus/Honors PreCalculus

Calculus/AP Calculus

Probability and Statistics/AP Statistics

Problem Solving/College Algebra

24. What science courses do you plan to take in high school?

Biology/AP Biology

Chemistry/AP Chemistry

Anatomy/Honors Anatomy

Physics/AP Physics

Environmental Science/AP Environ. Science

25. What computer courses do you plan to take in high school?

Multimedia I

Multimedia II

Programming I – Java

Programming II – Java

AP Computer Science - Java

Indicate answers for 26-28 by marking one box with an **X**.

26. If you had to pick your future career, which are would it be (Check only one box below).

- Architecture
- Business
- Computer/Technology
- Education
- Engineering
- Healthcare
- Journalism
- Legal Occupations
- Science
- Other (please specify)_____

27. Father's occupation (Check only one box).

- Architecture
- Business
- Computer/Technology
- Education
- Engineering
- Healthcare
- Journalism
- Legal Occupations
- Science
- Other (please specify)_____

28. Mother's occupation (Check only one box).

- Architecture
- Business
- Computer/Technology
- Education
- Engineering
- Healthcare
- Journalism
- Legal Occupations
- Science
- Other (please specify) _____

Thank you very much for taking the time to complete this questionnaire.

Your assistance in providing this information is appreciated. Your responses will assist in the exploration of gender issues in school mathematics. If you have any suggestion or would like to provide other information, please do so in the space provided below.

APPENDIX C
FLAGPOLE PROJECT

Name _____

Flagpole Project

The Problem

Estimate the height of the flagpole (in feet). You may not climb the flagpole nor attempt to throw anything at the flagpole.

Individual Write ups and Group Problem Presentation

- Each individual student must hand in his/her own write-up.
- The group will make a presentation as a whole.

Directions: Include each of the following items in both the write up and presentation.

I. The Solution:

Report your estimate of the height of the flagpole (in feet).

II. Solution Method:

Describe your method for finding the height of the flagpole. Convince your audience that this method was appropriate. Was this your original method?

III. Research Problems:

Describe all other solution methods your group discussed or considered. Did the group reject these methods? Why? Why did you finally settle on the method in section II? Why was this the best method? Discuss any problems you had with your solution development. This is so others interested in solving similar problems benefit from your research.

APPENDIX D
PAPER AIRPLANE PROJECT

Name _____

Paper Airplane Project
Research and Development (R&D)

Supplies Needed:

- A watch with a second hand or a stopwatch.
- Several measuring tapes (at least 50 feet).
- Several (about 5) sheets of plain white paper 8½”x11”.

Plane Design and Data Collection:

- I. Design and fold a paper airplane from one sheet of 8½”x11” paper. You may cut or tear the paper. You do not have to use all the paper. You may use other items in your airplane such as tape, glue, paperclips, etc. You will have to justify their use.
- II. Test your prototype ten times by tossing the plane. Record the length of time your plane stays in the air and the distance flown. Fill in the chart below. Make sure the plane is tossed approximately the same way each time by the same person.

Trial Run #1

Trial #	1	2	3	4	5	6	7	8	9	10
Time (secs)										
Distance (feet)										

III. Improve on your design.

Research aerodynamics and flight. Redesign your paper airplane. Redesign and fold a second paper airplane from one sheet of 8½”x11” paper. You may cut or tear the paper. You do not have to use all the paper. You cannot, however, use more paper. You may use other items in your airplane such as tape, glue, paperclips, etc. You will have to justify their use.

- IV. Test your redesign ten times by tossing the plane. Record the length of time your plane stays in the air. Record the distance flown (feet). Fill in the chart below. Make sure the plane is tossed approximately the same way each time by the same person.

Trial Run #2

Trial #	1	2	3	4	5	6	7	8	9	10
Time (secs)										
Distance (feet)										

Individual Write ups and Group Problem Presentation

- Each individual student must hand in his/her own write up.
- The group will make a presentation as a whole.

Directions:

Include each of the following items in both the write up and presentation.

I. Solution and Method:

Discuss and compare your two designs. Did the second design stay aloft longer? Did the second design fly further? Why or why not? What were the problems and assets of each design? Why did think the second design would be an improvement on the first design? Was it an improvement? Use your research and some form of data analysis to justify the second design.

II. Research Problems:

Describe other solution methods your group discussed or considered. Did the group reject these methods? Why? Why did you finally settle on the method in section II? Why was this the better method? Discuss any problems you had with airplane design, flight testing, or research. This is so others interested in solving similar problems benefit from your research.

APPENDIX E
BRIDGE PROJECT

Name _____

Bridge Project - Civil Engineering

The Problem

- I. Design a walking bridge to cross over the canal. You may not go in the canal at any time.
- II. Describe any issues or concerns you must take into consideration *before* planning and designing the bridge.

Research

- I. Research bridges and decide on the type of bridge that would be appropriate for going over the canal. Be ready to justify.
- II. Research the types of materials necessary to build the bridge and provide cost projections. Be ready to justify.
- III. Provide a scale drawing of your bridge.
- IV. Determine the most appropriate place for the bridge. Be ready to justify.

Individual Write ups and Group Problem Presentation

- Each individual student must hand in his/her own write up.
- The group will make a presentation as a whole.

Directions:

Include each of the following items in both the write up and presentation.

I. Solution and Method:

- Report on the bridge your group designed to cross over the canal. Discuss the building materials necessary. Include dimensions, location of the bridge, and other things you considered. Include a scale diagram of the bridge and the part of the canal traversed by the bridge.
- Describe your methods for finding the best bridge. Discuss all the factors you needed to take into consideration. Describe how you used these factors in your bridge decisions

II. Research Problems:

- Describe other solution methods your group discussed or considered. Why were some bridges rejected? Why did you finally settle on the bridge you ultimately chose? Why was this the best method? Discuss any problems you had with your bridge project. This is so others interested in solving similar problems benefit from your research.

APPENDIX F
ECOLOGY PROJECT

Name _____

Ecology Project

Ecology is the study of the relationship between living things and the environment.

Directions:

Pick one of the following ecology topics or come up with one of your own. Research the topic and be prepared to create an individual write up and make presentation to the class. The only real criterion for the project is that you use mathematics in some meaningful way.

Research:

Research your topic and be ready to discuss why you included certain things in your project and did not include certain things.

Individual Write ups and Group Problem Presentation

- Each individual student must hand in his/her own write up.
- The group will make a presentation as a whole.

Directions:

Include each of the following items in both the write up and presentation.

I. Solution and Method:

- Explain your project and the work your group did. Keep in mind that your classmates and your teacher will probably *not* be familiar with your project so be very clear explaining your project and your methods of solution.
- Explain why you choose this project.
- Describe your methods for working through your project. Discuss all the factors you needed to take into consideration. Describe how you used these factors while working on the project.

II. Research Problems:

- Describe other solution methods your group discussed or considered. Why were some ideas rejected? Why did you finally settle on the project method you ultimately chose? Why was this the best method? Discuss any problems you had with your project. This is so others interested in solving similar problems benefit from your research.

Choose from the following list of topics¹.

1. Recycling: How much of the things that we throw out could be recycled?
 - a. Research paper recycling. OR
 - b. Research aluminum cans recycling. OR
 - c. Research recycling of things you and your family no longer wants (those potential yard-sale offerings).

2. Don't Dump It: Which of these would you want in your drinking water? Furniture polish, paint thinner, or motor oil.
 - a. Research the effects of dumping these chemicals onto the ground. OR
 - b. Research the measures taken to recycle or dispose of these chemicals properly. OR
 - c. Research drinking water.

3. Wild Animals: Did you know that wild animals live in the suburbs and in cities?
 - a. Research the kinds of wild animals and their habitats found where you live or somewhere else that you can research. OR
 - b. Research wild animals and their habitats that live away from civilization.

4. Pollution: Why do some people have to boil their water before they can drink it? Pollution comes in many forms.
 - a. Research different forms of pollution OR
 - b. Research ways that your family or school pollutes OR
 - c. Research eco-friendly alternative that help combat pollution.

5. Come up with Your Own: You may come up with your own topic, but run it by your teacher for approval before you proceed with full-scale research.

¹ The topics were selected from the book:

Earth Works Group (1990). *50 simple things kids can do to save the earth*. Kansas City, MO: Andrews & McMeel.

APPENDIX G
GRADING RUBRIC

Name _____
 Projects

Grading Rubric		Total Points Available	Points Earned
Planning (10)			
1	Problem-solving plan is well thought out.	5	
2	Plan is clearly outlined.	5	
Group Dynamics (10)			
3	You are perceived to be a contributing member of your group.	5	
4	Group functions in a professional and efficient manner.	5	
Execution (20)			
5	Plan is executed as outlined.	10	
6	Revisions to the plan are made (if needed)* and clearly communicated.	10	
Solution (30)			
7	Solutions are clear and understandable.	5	
8	Appropriate units (inches, seconds, etc.) are used.	5	
9	Solutions are essentially correct OR if solutions are incorrect they are accompanied by possible explanations of why solutions are (or may be) incorrect.	20	
Presentation (30)			
10	Graphs are used (if needed).	5	
11	Diagrams are included (if needed).	5	
12	Written portion of the project is professional, legible, and neat.	10	
13	Oral presentation is understandable and professional.	10	
Total Number of Points		100	

Note: Any items listed in the rubric and were *not* needed will receive the full amount of points available.

Comments:

APPENDIX H
PROJECT REFLECTION

Name _____

Project _____

Please write a reflection on a separate sheet of paper about the project you just completed. Your reflection may be typed or legibly handwritten, but should discuss the following main ideas. You should have at least four paragraphs to cover each of the main ideas, but more may be necessary.

- 1) **Group dynamics:** Discuss your personal contributions to the project. Discuss how well the group worked, or did not work, together.
- 2) **The Project:** Discuss the actual working through the project. Did your group settle on a solution immediately? What mathematics did you use in the project? How did you conduct your research or solve the problem? What stumbling blocks did your group come across?
- 3) **The Presentation:** How did you feel about the presentation? Did your group's presentation adequately convey the project and your group's efforts? If you had to do the presentation again, what might you have included in the presentation that you did not? What might you have taken out of the presentation?
- 4) **Overall:** Give you overall feelings about the entire project. Was it a worthwhile experience? What did you learn? What more do wish we could have done? Discuss how you felt about this particular project. Did you find it interesting or boring? Explain

APPENDIX I
POST-QUESTIONNAIRE

Mathematics



Post-Questionnaire for Middle School Students

Please return your completed questionnaire to:

Barbara L. Clanton
Trinity Preparatory School
Winter Park, FL 32792

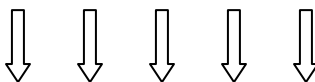
Please read each statement and indicate the extent to which you agree or disagree on a scale of 1 to 5, where 1 means you strongly disagree and 5 means you strongly agree.

Circle your responses.

START HERE

To what extent do you agree or disagree with the following statements?

1-Strongly Disagree	2-Somewhat Disagree	3-Neither Agree Nor Disagree	4-Somewhat Agree	5-Strongly Agree
---------------------	---------------------	------------------------------	------------------	------------------



- | | | | | |
|--|---|---|---|---|
| 1. The mathematics I learn in1
school is useful in everyday life. | 2 | 3 | 4 | 5 |
| 2. I will take more mathematics.....1
courses because they are useful. | 2 | 3 | 4 | 5 |
| 3. I feel confident that I will be.....1
able to learn the mathematics in
the next chapter in my math class. | 2 | 3 | 4 | 5 |
| 4. I will be able to learn Calculus..... 1 | 2 | 3 | 4 | 5 |
| 5. I would consider majoring1
in mathematics in college. | 2 | 3 | 4 | 5 |
| 6. I plan to take more than one1
mathematics course in
college. | 2 | 3 | 4 | 5 |
| 7. I would consider majoring.....1
in science in college. | 2 | 3 | 4 | 5 |
| 8. People who are <i>not</i> scientists1
or engineers use mathematics. | 2 | 3 | 4 | 5 |
| 9. My mathematics teachers think ...1
I am good at mathematics. | 2 | 3 | 4 | 5 |
| 10. I would consider majoring1
in computers/technology
in college. | 2 | 3 | 4 | 5 |

1-Strongly Disagree	2-Somewhat Disagree	3-Neither Agree Nor Disagree	4-Somewhat Agree	5-Strongly Agree
---------------------	---------------------	------------------------------	------------------	------------------



- | | | | | |
|---|---|---|---|---|
| 11. I plan on taking at.....1
least one AP mathematics
course in upper school. | 2 | 3 | 4 | 5 |
| 12. I will use mathematics even1
after I graduate from college. | 2 | 3 | 4 | 5 |
| 13. Mathematics is one of my1
best subjects. | 2 | 3 | 4 | 5 |
| 14. I do mathematics problems.....1
fairly easily. | 2 | 3 | 4 | 5 |
| 15. I use mathematics in my1
everyday life. | 2 | 3 | 4 | 5 |
| 16. My parents use mathematics.....1
in their lives | 2 | 3 | 4 | 5 |
| 17. I am able to do the MathCounts....1
problems-of-the-week successfully. | 2 | 3 | 4 | 5 |
| 18. Mathematics will be useful in1
my future career. | 2 | 3 | 4 | 5 |
| 19. I would consider majoring1
in engineering in college. | 2 | 3 | 4 | 5 |
| 20. I am good at mathematics.1 | 2 | 3 | 4 | 5 |

Indicate answers for 21-22 by marking the box with an **X**.

21. What grade are you in?

6th

7th

8th

22. What is your sex?

Female

Male

Indicate answers for 23-26 by marking each box that applies with an **X**.

23. What mathematics courses do you plan to take in high school?

Geometry/Honors Geometry

Algebra 2/Honors Algebra 2

PreCalculus/Honors PreCalculus

Calculus/AP Calculus

Probability and Statistics/AP Statistics

Problem Solving/College Algebra

24. What science courses do you plan to take in high school?

Biology/AP Biology

Chemistry/AP Chemistry

Anatomy/Honors Anatomy

Physics/AP Physics

Environmental Science/AP Environ. Science

25. What computer courses do you plan to take in high school?

Multimedia I

Multimedia II

Programming I – Java

Programming II – Java

AP Computer Science - Java

27. If you had to pick your future career, which are would it be (Check only one box below).

- Architecture
- Business
- Computer/Technology
- Education
- Engineering
- Healthcare
- Journalism
- Legal Occupations
- Science
- Other (please specify)_____

28. How have your experiences this year changed your intentions about majoring in science, technology, engineering, or mathematics in college or in taking science, technology, or mathematics courses in high school?

Thank you very much for taking the time to complete this questionnaire.

Your assistance in providing this information is appreciated. Your responses will assist in the exploration of gender issues in school mathematics. If you have any suggestion or would like to provide other information, please do so in the space provided below.

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