THE EFFECTS OF AN ENGINEERING-MATHEMATICS COURSE ON FRESHMEN STUDENTS' MATHEMATICS SELF-EFFICACY

By

FRED JAMES BARKER

A thesis submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE IN CIVIL ENGINEERING

WASHINGTON STATE UNIVERSITY
Department of Civil and Environmental Engineering

MAY 2010

To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of FRED JAMES BARKER find it satisfactory and recommend that it be accepted.

Shane A. Brown, Ph.D., Chair

Robert G. Olsen, Ph.D.

Jeffery C. Peterson, Ph.D.

ACKNOWLEDGEMENT

I would like to acknowledge the National Science Foundation, the College of Engineering and Architecture at Washington State University, and Wright State University for their support throughout this study.

It is also important that I acknowledge all of the people who helped me throughout the course of this project. First, I'd like to thank Dr. Shane Brown for his guidance and support as my advisor and committee chair. I would also like to thank the other members of my committee, Dr. Peterson and Dr. Olsen for their help. I thank Carrie Schramm and Devlin Montfort for their help conducting interviews, Laura Girardeau for help transcribing interviews, and David Street for his help with the coding process. For his constant support throughout the project I would also like to thank Kirk Reinkens, as well as the other Engineering 120 instructors for their willingness to help with the study.

THE EFFECTS OF AN ENGINEERING-MATHEMATICS COURSE ON FRESHMEN STUDENTS' MATHEMATICS SELF-EFFICACY

Abstract

by Fred James Barker, M.S.
Washington State University
May 2010

Chair: Shane A. Brown

In 2009, Washington State University introduced an engineering based mathematics course for incoming freshmen to improve students' understanding of pre-calculus and calculus concepts within the context of engineering applications. Because students with higher self-efficacy beliefs often have greater success in academics and increased retention in engineering (Lent, Brown, and Larkin, 1984; Chemers et al 2001; Schunk, 1991), this study was conducted to investigate the longitudinal effects of the course on students' mathematics self-efficacy. Previous research has demonstrated the importance of mathematics self-efficacy, but has been largely either qualitative or quantitative and rarely longitudinal. This study was conducted longitudinally using a quantitative survey instrument and qualitative, semi-structured interviews implemented on three occasions over four months with the eight students enrolled to examine effects of the course. For comparison, the survey was also implemented in another freshman-level engineering course. Results show that the class had a positive impact on students' mathematics self-efficacy. Survey results show that mathematics self-efficacy increased sharply during the course and was sustained into the following term. Analysis of

interview data supports survey findings regarding the impact of the class and add findings detailing themes related to perceived efficacy experiences. Mastery and vicarious experiences were the most prevalent of Bandura's (1997) four sources of self-efficacy found in this study. It is apparent that the students' mathematics self-efficacy did increase as a result of the course. Understanding if, how, and why students' mathematics self-efficacy beliefs change over time provides information that educators can use to develop teaching methods and curriculum.

Table of Contents

List of Tables

List of Figures

DEDICATION

This thesis is dedicated to my Mom, Dad, and girlfriend, Layne, for their love and support.

I. Introduction

During summer 2009, Washington State University introduced an engineering based mathematics course for incoming freshmen, done as part of a project in conjunction with Wright State University. The goal of the course was to improve students' understanding of pre-calculus and calculus concepts within the context of engineering problems. It was also intended to increase students' interest in engineering, through the integration of mathematics and engineering concepts. Typically, students who come to college intending on majoring in engineering have math backgrounds at or above the pre-calculus level. At WSU, 75 percent of students entering engineering place into pre-calculus or higher, while all students in the course had taken at least high school pre-calculus prior to enrollment. Because of this, an underlying assumption for the course was that the students already had some pre-calculus experience, but needed more work to understand and fully grasp the material, rather than a holistic study of the subject matter. The inclusion and use of engineering contexts to teach mathematics was done to help students see practical applications of the material in engineering, which would, in turn, help them see uses in future mathematics courses. This is important because engineering students often become disinterested in engineering, or even change majors, because of the rigorous mathematics prerequisites required (Adelman, 1998; Klingbeil et al, 2005).

After completion of this course, students should have a better understanding of the material, be better prepared for college mathematics courses, and have greater interest in engineering, potentially leading to increased retention. Based on these possible outcomes, mathematics self-efficacy was chosen as a research topic because students who have higher self-efficacy beliefs tend to be more apt to succeed in academics and persist longer in the curriculum (Lent, Brown, and Larkin, 1984; Chemers et al, 2001; Schunk, 1991). As a result, the study revolved around the ability of the course to change students' mathematics self-efficacy. These changes were explored longitudinally using a mixed methods approach.

A. Mathematics Self-Efficacy

Self-efficacy, according to Bandura, "refers to beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments." (Bandura, 1997, p. 3) Mathematics self-efficacy, then, is the confidence one has in their ability to do mathematics. It is important to look at measurements of self-efficacy beliefs, as well as the way that those beliefs are developed. Self-efficacy beliefs are ever-changing as people raise or lower them constantly. A variety of survey instruments and scales have been developed and used to measure mathematics self-efficacy. The Mathematics Self-Efficacy Scale (Betz and Hackett, 1983), one of the most frequently used instruments, examines students' self-efficacy beliefs related to mathematics tasks, problems, and courses. Other researchers have also used one or more of these self-efficacy constructs in their instruments (Lent, Lopez, and Bieschke, 1991; Schulz, 2005; Pajares and Graham, 1999). Bandura (1997) has described the four sources of self-efficacy development: mastery experiences, vicarious experiences, social persuasions, and physiological or affective states. It is important to note that self-efficacy experiences can be either positive or negative. Mastery experiences come from a person's previous performance or actions. An example of a positive mastery experience would be a student who received an "A" grade on a test. Vicarious experiences are comparisons to others. These experiences are characterized by the thought that "if someone else can do it, so can I." Social persuasions come from verbal persuasions that a person is capable. This would be when someone concludes, for example, "I think I can do it because my teacher says that I can." Physiological states refer to a person's state of mind. Anxiety, excitement, stress, and other emotions or states of mind characterize these physiological states. The four sources are widely accepted and have been found evident in almost all mathematics self-efficacy studies. Research has consistently shown that mastery and vicarious experiences are the most influential to the development of mathematics self-efficacy (e.g. Usher, 2009; Usher and Pajares, 2009; Bandura, 1997).

Mathematics self-efficacy is an important topic related to academic achievement and retention. Increased levels of self-efficacy, as Bandura (1997, p. 43) stated, lead to increased "perseverance" and a "higher likelihood that the chosen activity will be performed successfully". Students with high levels of mathematics self-efficacy tend to have increased expectations and performance levels (Chemers et al, 2001; Lent, Brown, and Larkin, 1984). Schunk (1991) also indicated that self-efficacy leads to increased effort and higher persistence. Mathematics self-efficacy has also been shown to be important in motivation and retention of students in mathematics and science majors (Lent, Brown, and Larkin, 1984; Schunk, 1991; Klingbeil et al, 2005). Curriculum demands and decreased interest in science, mathematics, and engineering degree programs have been found to be important factors for students switching majors, as a result of decreased self-confidence in engineering and mathematics concepts (Seymour and Hewitt, 1997). There have been a number of studies that have shown that students with increased levels of mathematics self-efficacy are more likely to choose majors and careers that involve more mathematics, like engineering (Betz and Hackett, 1983; Zeldin and Pajares, 2000; Lent, Lopez, and Bieschke, 1991). Researchers have also investigated the differences between freshmen students in remedial mathematics courses with their counterparts in calculus (Hall and Ponton, 2005; Hagedorn, et. al, 1999). They clearly demonstrated that students in the developmental mathematics courses exhibited lower levels of mathematics self-efficacy. Students who struggle with mathematics and have lower confidence are more likely to become frustrated with mathematics or choose majors without substantial mathematics components (e.g. Betz and Hackett, 1983; Lent, Brown, and Larkin, 1984).

Mathematics self-efficacy has been investigated extensively using quantitative methods, most commonly survey instruments (e.g. Lent, Lopez, and Bieschke, 1991; Betz and Hackett, 1983). Quantitative research often views mathematics self-efficacy in its relatedness to other factors or outcomes like career choice (e.g. Betz and Hackett, 1983; Lent, Lopez, and Bieschke, 1991) or level of mathematics ability (Hall and Ponton, 2005). The Mathematics Self-Efficacy Scale (MSES), developed by Betz and Hackett in 1983, has been frequently used to quantitatively measure the mathematics self-efficacy of college students (e.g. Lent, Lopez, and Bieschke, 1991; Walsh, 2008; Betz and Hackett, 1983; Hall and Ponton, 2005). This instrument measures students' mathematics self-efficacy beliefs through problem, task, and course related confidence levels using a Likert scale. The MSES is a tested and reliable survey instrument as demonstrated through both internal consistency reliability values and factor analysis, having coefficient alphas ranging from .90 to .96 (Betz and Hackett, 1983; Lent, Lopez, and Bieschke, 1991; Pajares and Miller, 1995; Kranzler and Pajares, 1997).

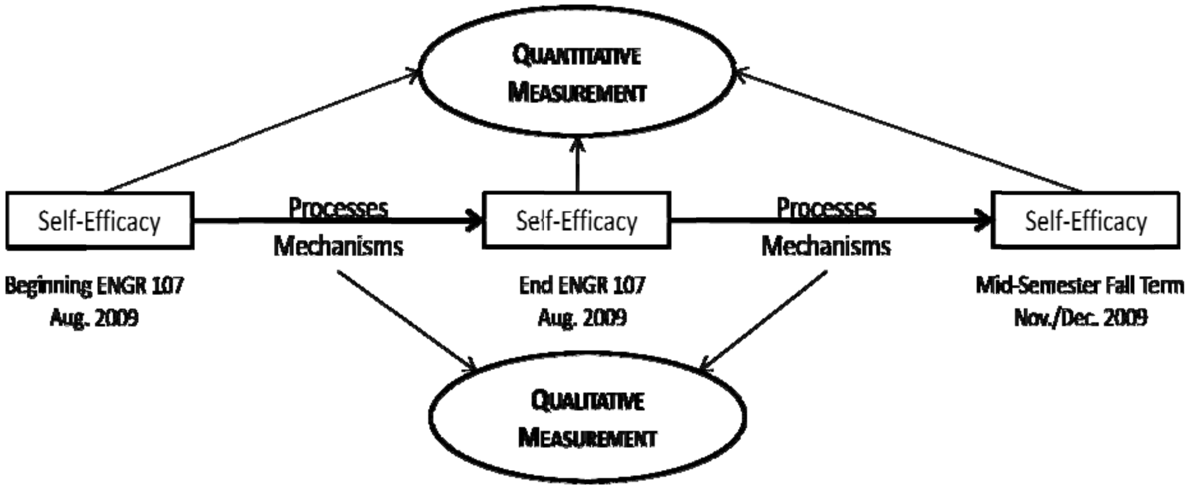
Qualitative research has also been used to explore mathematics self-efficacy, but not to the extent that quantitative research has. These types of studies often focus on how mathematics self-efficacy is developed or answer other “why” and “how” questions that cannot be answered by quantitative research. One such interest is in gender differences. Because fewer women than men choose careers involving mathematics, qualitative research has been done to determine how women build mathematics self-efficacy and how it affects their career decisions (Coyle, 2001; Zeldin and Pajares, 2000). Other studies have focused on the four sources of self-efficacy and how they are developed (Usher, 2009; Hutchison-Green, Follman, and Bodner, 2008; Zeldin and Pajares, 2000). Interview methodologies have been used to gain an in-depth understanding of how mathematics self-efficacy is developed and are the primary qualitative method used in studying mathematics self-efficacy (Usher, 2009; Zeldin and Pajares, 2000).

Self-efficacy has been used to study, understand, and evaluate the effectiveness of new courses or teaching methods because of its relationship to academic success, motivation, and persistence. Hodges and Murphy (2009) examined sources of mathematics self-efficacy for an online algebra course, while Maag (2004) used mathematics self-efficacy as part of her study on new multimedia teaching methods in nursing. Schunk (1981) studied how varying teaching methods affected children's self-efficacy and skill related to elementary division. Mathisen and Bronnick (2009) used creative self-efficacy as a direct measure of the effectiveness of an art class.

To this point, mathematics self-efficacy research has been largely done at a single point in time. Few studies have examined mathematics self-efficacy longitudinally. One such study was done to investigate the changes of self-efficacy of first year engineering students (Hutchison-Green et al, 2008). The authors were able to identify changes and reasons for change over the course of students' first year through semi-structured interviews. This study however, investigated engineering self-efficacy, as opposed to mathematics self-efficacy. A study done by Mathisen and Bronnick (2009) studied creative self-efficacy longitudinally using only quantitative measures. The study was conducted to determine the effect of a creative art class on self-efficacy. Gore's research on academic self-efficacy (2006) brings to light another reason for longitudinal methods. He found that academic self-efficacy prior to college is a weaker predictor of academic success than is reported self-efficacy at the end of the first term of college (Gore, 2006). It is then important to monitor the endurance and lasting quality of mathematics self-efficacy changes.

The use of both qualitative and quantitative methods, also known as mixed methods, has been rarely used in the study of self-efficacy. Mixed methods have been used before to study academic self-efficacy (Perry et al, 2007) and career decision-making self-efficacy (O'Brien et al, 2000) to compare methods and use data triangulation. Mixed method studies in mathematics self-efficacy, however, are lacking. Although they have not been often used, Teddlie and Tashakkori (2009, p. 33) propose that "A major advantage of mixed methods research is that it enables the researcher to simultaneously ask confirmatory and exploratory questions and therefore verify and generate theory in the same study."

Research conducted in this study used both qualitative and quantitative approaches to explore the longitudinal effects on mathematics self-efficacy from an engineering mathematics course. Previous research has been primarily qualitative or quantitative and rarely longitudinal. By using a mixed methods approach, the study was able to investigate if mathematics self-efficacy beliefs changed over time, as well as how and/or why they changed. Figure 1 shows a basic outline of the research timeline and methods used. The quantitative methods allow for measurement of mathematics self-efficacy at multiple times, while the qualitative methods provide insight into the processes and mechanisms that lead to the observed changes. It is important that this study was done longitudinally to examine the endurance of witnessed changes in mathematics self-efficacy beliefs.



II. RESEARCH QUESTIONS

The goal of this study was to investigate changes in and reasons for change in students' mathematics self-efficacy and to answer the following research questions:

- Do the mathematics self-efficacy beliefs of freshmen students enrolled in the Engineering 107 course change during and after the course?
- How and/or why do the mathematics self-efficacy beliefs of students enrolled in Engineering 107 change during and after the course?

III. RESEARCH SETTINGS AND PARTICIPANTS

The Engineering 107 (ENGR 107) course described in this research was a newly developed class taught at Washington State University located in Pullman, WA. The course targets incoming freshmen with intended majors in any of the engineering disciplines. It was offered through the College of Engineering and Architecture and was taught by civil engineering faculty. The College of Engineering and Architecture is home to nearly 2500 undergraduate students as of 2008.

The ENGR 107 class was offered three weeks prior to the start of the fall semester in the summer of 2009. The course consisted of two hours of lecture and three hours of laboratory time, five days a week. The lecture was taught by an assistant professor in the Department of Civil and Environmental Engineering who has a reputation as a good teacher with both students and faculty, eight years of teaching experience, and a research focus in engineering education. The laboratory was instructed by two civil engineering students, one graduate student with prior experience as a laboratory instructor and one junior undergraduate. Both students are well respected, enthusiastic, and high achieving students within the department. The first two weeks of the class focused on pre-calculus concepts, while the final week introduced basic differential and integral calculus.

Placement into mathematics courses at WSU is done using either the mathematics placement exam or SAT/ACT scores. Minimum requirements for placement into mathematics courses have been established to ensure students are enrolled in appropriate level courses. Students that had enrolled in ENGR 107 had placed at or below the pre-calculus level via placement test or SAT/ACT scores. At the end of the second week of ENGR 107, students took the mathematics placement test and were also given the option of taking it again at the conclusion of the course. ENGR 107 gave students the opportunity to improve their mathematics course placement by way of the placement exam.

ENGR 107 was unique because it was not taught during a normal academic term. Students who participated in the present study came to college three weeks early and spent five hours a day in class, which isolated them. This was one reason the class was chosen, as outside influences were minimal. Because students were immersed in ENGR 107, cause and effect relationships were more plausible and easily identified. Students were not involved in any other concurrent coursework, limiting the effects of outside influences.

The ENGR 107 course in the summer of 2009 had eight students enrolled. There were seven male students and one female student. The intended majors were bioengineering (3), chemical engineering (2), mechanical engineering (1), civil engineering (1), and undecided engineering (1). All students were first-year, freshmen with ages ranging from 18 to 19 years old. Students enrolled in the course were asked if they would be willing to participate in the study. All eight students agreed to participate, although one student did not participate in the third interview or survey implementation.

For comparative purposes, the mathematics self-efficacy survey instrument discussed later was also implemented in two sections of Engineering 120 (ENGR 120), an introductory engineering class for freshmen. This class was chosen because it is required for all engineering majors and consists of nearly all freshmen. The surveyed sections had 44 and 45 students each. Students were asked if they would be willing to participate in the research by completing two surveys during the semester. Thirty-four students from both sections agreed to participate representing 77.3 and 75.6 percent of each section.

IV. Research Methods

Qualitative and quantitative methods were used to investigate changes in students' mathematics self-efficacy and gain a more holistic overview of if/how/why students' mathematics self-efficacy changed. Mixed method studies consist of both qualitative and quantitative methods. The quantitative aspect of mixed methods studies uses statistical analysis of data and often requires considerably larger samples relative to qualitative methods (Teddlie and Tashakkori, 2009). In quantitative research, descriptive statistical methods are used to "understand the data, detect patterns and relationships, and better communicate the results", while inferential statistical methods are "based on estimations of how much error is involved in obtaining a difference between groups or a relationship between variables" (Teddlie and Tashakkori, 2009, p. 258). Inferential statistics were inappropriate for this study because of the small sample size; however, descriptive statistics were still useful. Because there were only eight students in ENGR 107, the research approach for this study was quasi-mixed methods, as statistical significance cannot be obtained with such a sample. Even though quantitative data in this study is insufficient for complex statistical analysis, the results are still useful and provide insight into how students' mathematics self-efficacy changed over time.

A. Surveys

A survey instrument was used to provide a quantitative measure of students' mathematics self-efficacy. This survey was developed by Betz and Hackett in 1983 and revised for reproduction in 1993. It was developed to explore mathematics self-efficacy of students at the college undergraduate level. The original survey consisted of three subscales: mathematics tasks, mathematics problems, and mathematics courses. The tasks subscale involves everyday uses of mathematics like calculating tax, while the problems subscale uses arithmetic, algebra, and geometry problems. The courses subscale relates to students' confidence in their ability to succeed in college courses like calculus. The revised version includes only the tasks and courses subscales in order to shorten and simplify the instrument, even though "research has provided solid evidence for the reliability and validity of all three sections" (Betz and Hackett, 1993, p. 5). For this study, a two-part instrument was used that included the problems and courses subscales, as designed and implemented by Betz and Hackett (1983; 1993). The problems and courses were chosen because students' attitudes towards their capabilities to solve problems and be successful in future mathematics courses were valued data. Tasks were not relevant or of interest to this research study. Part I consisted of 18 mathematics problems focused on arithmetic, algebra, and geometry. These problem areas were embedded in the ENGR 107 course and are fundamental to success in almost all mathematics courses, making them important to students in a curriculum that is heavy in mathematics. Students were required to rate confidence in their abilities to solve the problems using a ten point (0-9) Likert scale. Three sample questions are listed below in Figure 2.

WSU ID Number: ________________

Part I (Cont.)

No Confidence at all	Very little Confidence			Some Confidence		Much Confidence		Complete Confidence	
0	1	2	3	4	5	6	7	8	9

How much confidence do you have that you could successfully solve:

5. The opposite angles of a parallelogram are ________.	0	1	2	3	4	5	6	7	8	9
6. Five points are on a line. T is next to G. K is next to H. C is next to T. H is next to G. Determine the relative positions along the line.	0	1	2	3	4	5	6	7	8	9
7. There are three numbers. The second is twice the first, and the first is one-third of the other number. Their sum is 48. Find the largest number.	0	1	2	3	4	5	6	7	8	9

Figure 2: Sample Survey Questions

Part II uses the same scale, but students were required to rate confidence in their ability to pass 16 college level courses involving mathematics with a "B" grade or better. The courses used were those used in the 1983 version of the MSES. Of the 16 courses, eight are mathematics courses, while the others are courses that involve mathematics. The courses include Basic College Math, Economics, Statistics, Physiology, Calculus, Business Administration, Algebra I, Algebra II, Philosophy, Geometry, Computer Science, Accounting, Zoology, Trigonometry, Advanced Calculus, and Biochemistry.

There were 18 math problems and a total of 16 courses, giving the survey an overall length of 34 items. Mathematics self-efficacy scores were determined for the overall survey, as well as the individual parts. The students in the ENGR 107 class were given the survey three times: at the beginning and end of the course, as well as midway through fall semester. Students in the ENGR 120 sections were surveyed twice: at the beginning of and midway through fall semester, which correspond with the second and third surveys of students in the ENGR 107 course. The entire survey instrument can be found in Appendix B.

B. Interviews

The aforementioned survey instrument would provide only part of the desired results. Survey results can yield information as to whether and how much change in students' mathematics self-efficacy beliefs occurred. This does not, however, provide enough context as to how or why those beliefs changed. Interviews helped provide a more complete understanding of students' mathematics self-efficacy beliefs and allowed for the collection more in-depth, detail-rich information that could not be obtained from the survey alone. To further examine these details between survey implementations, qualitative research was conducted using semi-structured interviews. For example, students were asked on the survey to report confidence in passing college courses, while in the interviews they were asked what made them feel the way they do about upcoming college mathematics courses. Students' confidence in their mathematics abilities and confidence that they could be successful in future mathematics courses were used as operational definitions of mathematics self-efficacy during interviews. The interview protocols were intended to be non-descriptive and allow students to elaborate and demonstrate changes in self-efficacy using constructs they found important.

The interview protocols were developed based on a study done by Usher (2009) that investigated the sources of mathematics self-efficacy beliefs of middle school students. Usher (2009) focused her questions in categories that included background, experiences, environment, mathematics and other people, and physiological responses. The interview protocols used in this study followed the same logic and were designed to elicit responses regarding sources of students' self-efficacy beliefs and factors that influence them. The first interview protocol focused on students' mathematics backgrounds and beliefs. It asked questions about high school and family. This interview protocol was also designed to elicit students' expectations for the ENGR 107 course. The second and third interviews were shaped using the same principles, but also built on knowledge gained from the previous interviews and focused on how and why the students' self-efficacy beliefs had changed. The post-class protocol was focused on the ENGR 107 course and how it affected the students' mathematics self-efficacy beliefs through the four main sources. Students were asked to describe positive and negative aspects of the course, as well as their perceptions of the placement test and upcoming mathematics courses. The final interview was focused on students' current mathematics courses. Students were asked to recall experiences from ENGR 107 and describe how those had affected them in their current coursework. From this, it was possible to examine lasting effects of the ENGR 107 course. Table 1, below, provides sample interview questions from each of the three interviews to show the progression and thought process, while the full protocols can be found in Appendix A.

Sample Questions
<u>Start of ENGR 107</u> What do you expect as a result of taking this course [ENGR 107]? What has your family told you about how you are in math? What sort of study habits do you have in math? <u>End of ENGR 107</u> What experiences have affected your confidence in math? How and why? Do you think this class has helped prepare you for math classes in college? Why or why not? How would you say you compare to the rest of your classmates in your math abilities? Would you recommend ENGR 107 to other students? Why or why not? <u>Mid-Semester Fall Term</u> What math class are you currently in? How is that class going for you? Tell me about some experiences from ENGR 107 that helped prepare you for this class? Tell me about some positive and negative aspects of the class [ENGR 107]. What would you tell somebody it [ENGR 107] will do for their confidence?

Table 1: Sample Interview Questions

Interviews were conducted with the eight students in ENGR 107. Students participated in three interview sessions lasting approximately one half hour each. The interviews were done in coordination with the three surveys; before and after the ENGR 107 course, and once mid-semester of fall term. All interviews were tape recorded and transcribed verbatim for analysis. The first two sets of interviews were conducted by two graduate students in the Department of Civil and Environmental Engineering not involved in the implementation of the course. This was done because the primary researchers were involved in teaching the class and, therefore, might have an influence on students' responses. The primary researchers conducted the final round of interviews, as it was done three months after the course had concluded.

V. Data Analysis

An important deviation from the original scale was that not all of the courses were used in data analysis. The MSES courses subscale included eight courses that are math related, but not directly mathematics courses (i.e. Accounting). Students are unlikely to take these non-mathematics courses later in the engineering curriculum. Only the eight mathematics courses were used for analysis. This was done because the focus of this study was specifically on mathematics and engineering. Results from the other courses may have introduced unneeded error because the courses were not as relevant to engineering and because students may not have known what is involved in these courses and likely would not have been able to tie mathematics to them, like zoology for example. Bandura (1997) speaks to the idea that people are not capable of judging their own self-efficacy if they don't understand the task at hand. In this study, students might not have understood the tasks of the non-mathematics courses or might have linked their self-efficacy beliefs for those courses to abilities in science or other academic areas instead of mathematics. These beliefs, then, would not have provided accurate descriptions of students' *mathematics* self-efficacy beliefs and were, therefore, not included in analysis. Courses used for analysis, as well as those not used are provided in Table 2. In the analysis, Part II represented only the eight mathematics courses.

Courses Included	Courses not Included
Basic College Math	Economics
Statistics	Physiology
Calculus	Business Administration
Algebra II	Philosophy
Geometry	Computer Science
Algebra I	Accounting
Trigonometry	Zoology
Advanced Calculus	Biochemistry

Table 2: Part II Mathematics Courses

Surveys were scored using the procedures identified by Betz and Hackett in the manual for using the MSES (1993). Each student was given an average mathematics self-efficacy score for Part I and Part II separately and collectively. For analysis, the separate part scores were used in order to distinguish differences between problem and course related mathematics self-efficacy. Survey averages and standard deviations were obtained for the three survey implementations, as well as the two done with the ENGR 120 classes for comparison. Due to the small sample size (n=8) in this study, descriptive methods were used, however inferential methods were inappropriate and not used.

Analysis of the interview data was done using thematic analysis as described by Miles and Huberman (1994). The interview transcripts were first coded in-vivo, or with the words that the students used. Codes were then grouped into patterns and finally into major themes. The focus of this study was how students' mathematics self-efficacy was developed and influenced through the four sources of self-efficacy. In this light, themes and patterns were then related to the four sources. Themes not related to mathematics self-efficacy were identified, but not described in this article. The interviews were coded three times over six months to ensure that information was not overlooked. During the coding process, complete responses or experiences were used as the unit of analysis. A code, for example, might be a question and an entire student response. This was done because self-efficacy beliefs are developed through experiences and the researchers felt that it was important to examine the full experience, instead of smaller units. In light of this idea, a response or experience could have multiple codes associated with it. The coding and analysis was checked with multiple coders to ensure that personal bias was limited. An inter-coder reliability score of 83 percent was found using methods described by Miles and Huberman (1994). This was accomplished by two researchers coding and analyzing one complete interview. Both researchers coded the interview for positive and negative experiences of self-efficacy development through Bandura's four sources. Each researcher also identified the associated context of the experience (i.e. placement test, comparisons to other students, etc.). The researchers then compared the coding process and discussed differences and ascertained the inter-coder reliability score by dividing the number of matching codes by the total number of coded quotations. No major disagreements on codes were present. Discrepancies revolved around the length of quotations and/or minor quotations that were overlooked by one of the researchers. When quotations are used from interviews, the preceding questions, as well as responses, are provided to give appropriate background and context. Throughout this paper pseudonyms were used in place of students' names to protect their identities.

VI. Results and Discussion

A. Survey

The survey consisted of one part on problem solving and one part on confidence in being successful in future mathematics courses. Students were required to rate their confidence, on a scale of 0-9, for both parts. Figures 3 and 4 show the students' mathematics self-efficacy survey scores for Parts I and II, respectively. All eight students are charted, as are the averages for students in the ENGR 107 course and the ENGR 120 classes for comparison. Errors of one standard deviation are shown for both class averages. From the figures, it is clear that there are two distinct and different changes in mathematics self-efficacy. From the beginning to the end of ENGR 107, the scores increased noticeably, while after the course the scores seem to level off. Because of these distinct regions, further discussion will be done regarding time during and after the ENGR 107 course.

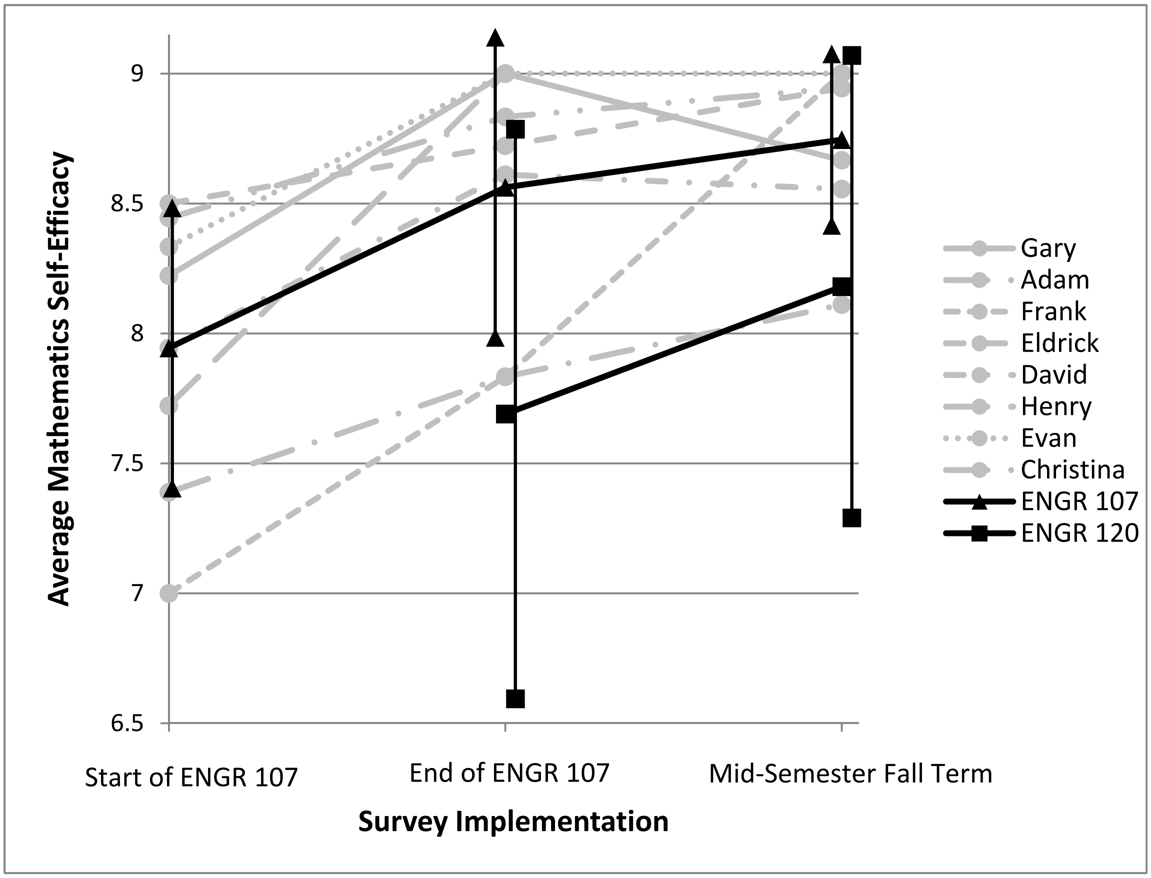


Figure 3: Timeline of Students' Mathematics Problem Self-Efficacy

i. During Engineering 107

The averages for both Parts I and II increased over the course of the class. The initial average for Part I was 7.94 with a standard deviation of .54, while the average at the end of the class was 8.56 with a standard deviation of .58. For Part II the averages were 7.28 and 7.92 with standard deviations of .52 and .64, respectively. In both parts, students experienced sharp increases in their perceived mathematics self-efficacy beliefs over the course of ENGR 107.

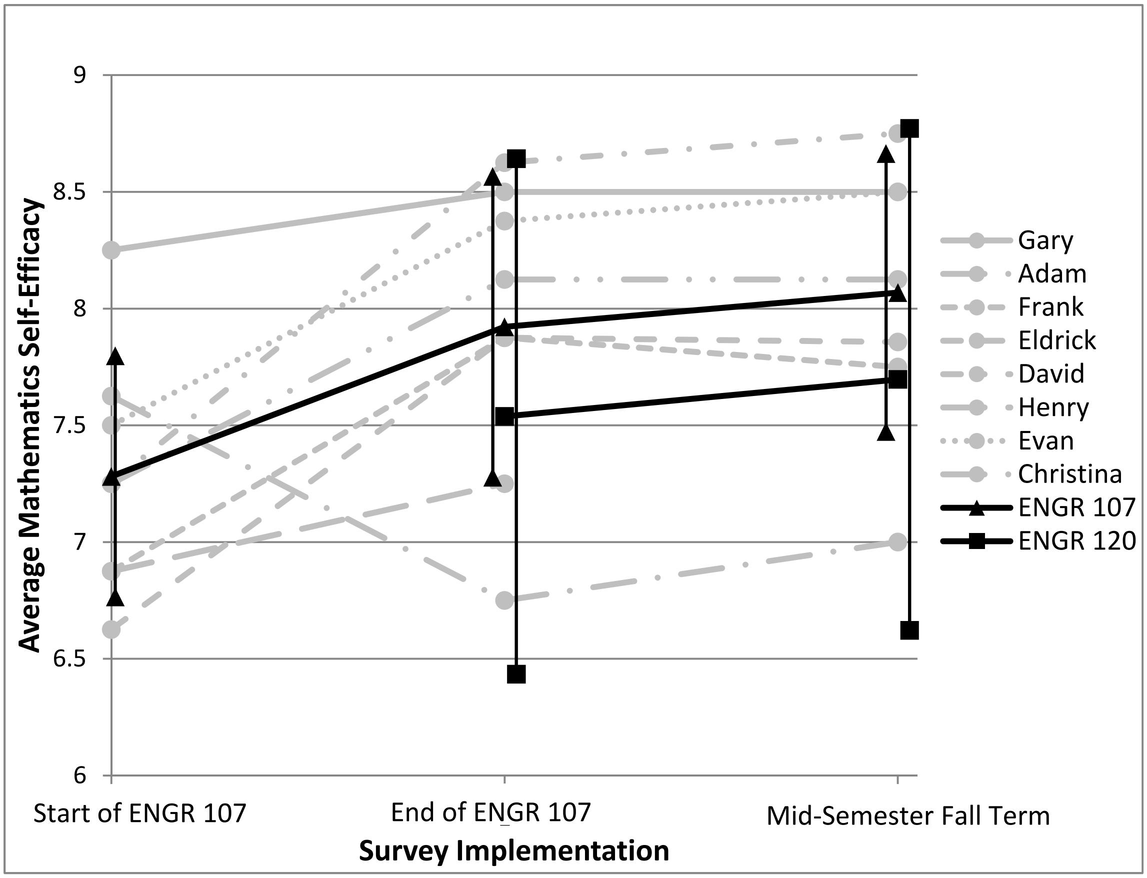


Figure 4: Timeline of Students' Mathematics Courses Self-Efficacy

ii. After Engineering 107

The third implementation of the survey, mid-semester fall term, provided results that were substantially different than the results from the beginning to the end of the course. For Parts I and II, the averages were 8.75 and 8.07 with standard deviations of .33 and .60 respectively. These averages were only slightly elevated in comparison to the averages immediately following the course of 8.56 and 7.92. Figures 3 and 4 show that students demonstrated leveling mathematics self-efficacy scores for both sections of the survey. Students experienced various changes in their self-efficacy beliefs including increases, decreases, and some that remained unchanged. Unlike during the course, however, students did not experience major changes in their mathematics self-efficacy beliefs. These results closely match those from Mathisen and Bronnick (2009), who found that a creative art class increased self-efficacy sharply during the course, with those beliefs leveling off and being sustained after the class. The students in ENGR 107 were able to increase their mathematics self-efficacy beliefs during the course and sustain those beliefs during their first semester of college mathematics.

iii. Engineering 120 Comparison

For a comparative baseline, surveys were conducted with two sections of ENGR 120. The surveys were implemented twice, in conjunction with the ENGR 107 students' second and third survey implementations. This data was obtained for a comparative baseline for the students in ENGR 107 because both groups consisted of freshmen students intending on pursuing engineering degrees. The results from these surveys can be seen in Figures 3 and 4. Both averages for Parts I and II showed a modest increase in mathematics self-efficacy between the two implementations. The ENGR 120 Part I average mathematics self-efficacy scores were 7.69 and 8.18 with standard deviations of 1.10 and .89 respectively. For Part II, they were 7.54 and 7.69 with standard deviations of 1.10 and 1.07. For both Parts I and II, the averages from ENGR 107 and ENGR 120 have nearly parallel trends of slight increases in mathematics self-efficacy beliefs. Interestingly, the ENGR 107 average is higher than the ENGR 120 average, though there are relatively high standard deviations. Students in ENGR 107 had mathematics self-efficacy beliefs before the course roughly equal to those of students starting ENGR 120. Because of the sharp increase experienced during the ENGR 107 class, those students started fall term with higher average mathematics self-efficacy beliefs than their counterparts in ENGR 120.

These results are very indicative of an increase in mathematics self-efficacy over the course of the ENGR 107 class. They also indicate the viability of the lasting effects of the course on students' mathematics self-efficacy beliefs. The survey results, however, only indicate that mathematics self-efficacy beliefs did increase over the course of ENGR 107. The surveys give no indication of how or why these beliefs changed, which was explored using the interview data. Although other factors and variables are likely to exist, the increases in students' mathematics self-efficacy can at least be partially attributed to the course itself. This hypothesis will be further supported through the qualitative results.

B. INTERVIEWS

Indications of all four sources of self-efficacy proposed by Bandura (1997) were found in this study. The most prevalent of these were mastery experiences and vicarious experiences. There were few instances of social persuasions or physiological states in relation to the ENGR 107 course. Throughout the interviews, mathematics self-efficacy was operationalized as students' perceived mathematics abilities or their perceived ability to be successful in future mathematics courses. Students described experiences as affecting their mathematics self-efficacy using both constructs, corresponding well with the problems and courses sections of the survey.

i. Mastery Experiences

Mastery experiences were described by students more frequently than any other source of self-efficacy in this study. Students repeatedly described mastery experiences as factors that influenced their levels of confidence. The mastery experiences identified were largely positive. Positive themes became apparent: learning the material, obtaining desired grades, having a positive start to college, and improved placement test scores. While positive experiences were more prevalent, there were some that had a negative effect on students' mathematics self-efficacy, primarily in regard to students' placement test scores.

Students consistently described mastery experiences about learning the material, grasping concepts, reviewing previously forgotten material, and working through problems. A very typical mastery experience about learning the material can be seen in the following quote from Evan.

> *Interviewer: Are there any particular experiences in 107 that help made you feel ready for [calculus]?*
>
> *Evan: Um, I don't know. I mean I think the overall just grasping these new concepts like by myself like it just the stuff on the board doesn't really translate to me… like right off the bat…so taking notes and then I think during the lab just asking questions and like getting some further answers.*
>
> *Interviewer: Yeah.*

Evan: I think is what really prepared me…They wouldn't…give you the answers they'd like give you steps to find it and once you figure it out yourself…you feel a lot more confident in your abilities and you can do the next one and next one and then pretty soon you know the stuff and...

Interviewer: Yeah.

Evan: It's no problem.

Evan commented that once he was able to figure out one problem, he had increased confidence that he could do the next one. This is a sentiment that was identified by many of the students. On a number of occasions, students would talk about how the course helped them "figure things out". Another student, Frank, spoke about how he was pleased with the class and how he was able to learn material that he might have missed or forgotten in high school.

Interviewer: After taking the class, how would you say your confidence in math changed?

Frank: A lot higher. There was a lot of unknowns when I was coming into class, because I didn't know any trig or pre-calc stuff before this, so I didn't know what I was coming into exactly. But now that I have gone through it and know everything I was missing before, it's a lot higher. A lot better.

David described his sentiments on the value of ENGR 107, by describing that working through the course and the material that he knew he could succeed in calculus.

Interviewer: In what ways did Engineering 107 help you feel confident in your math abilities?

…

David: Um, it was just way to work out problems and make sure I was going to be in the right math course. That gave me a lot of confidence because it sort of proved to me that I don't need to…that I can be in calculus and do well. I can do well in pretty much any math class if I just do the work and stuff. So after that I was certain that calculus was doable, whereas before, I had trouble in high school. But now I'm confident.

Receiving high grades, being successful on tests, and having a good first experience in college also seemed to give students increased levels of mathematics self-efficacy. Eldrick talked about how ENGR 107 helped prepare him for college mathematics courses, as well as improve his confidence.

Interviewer: Were there any experiences specifically from the class [ENGR 107] that helped prepare you or made you feel more confident going into your new math, as opposed to just being on campus?

Eldrick: I think, I mean we had like 8 or 9 students in the Engineering 107 class, so it was real easy to ask a question. It was way easier even than high school, because we knew each other by Week 1. We were basically living together 5 hours a day. Being successful on the tests…I know a lot of people screwed up one problem on the test, and Dr. Brown was like 'Take it home and redo it.' He wants us to learn it, instead of marking it wrong. So that was really cool.

Interviewer: So is that something that helped make you more confident, being successful in that class?

Eldrick: Definitely. When I get an A in the first class, I'm like, 'I can do this.' 'We can work through it.'

Interviewer: So did that improve your confidence?

Eldrick: Yeah, definitely.

The sentiments felt by Eldrick were expressed by other students as well. It seems to be important for students to start off college on the right foot. In the words of David, "It's nice to be able to focus on one class and get an A in it and you know, sit down and have a good start on your GPA."

The mathematics placement test was the basis for both positive and negative mastery experiences. Students often recounted negative experiences because of their initial placement scores, while many also gained positive experiences by receiving increased scores when they retook the test. Table 3 shows students' course placement based on the mathematics placement test. All students took the placement test during the second week of ENGR 107, and three took it again at the end of the course. Initial placement test scores are only given for five students because three had not taken it prior to enrolling in ENGR 107. By the end of the course, all students had improved their course placements by at least one course level.

Name	Initial	8/14/09	8/20/2009
Adam	MATH 99: Algebra	MATH 106: College Algebra	MATH 106: College Algebra
Eldrick	Did not take	MATH 107: Pre-Calculus	
Christina	Did not take	MATH 171: Calculus I	
David	MATH 107: Pre-Calculus	MATH 171: Calculus I	
Frank	MATH 107: Pre-Calculus	MATH 171: Calculus I	
Evan	MATH 107: Pre-Calculus	MATH 107: Pre-Calculus	MATH 171: Calculus I
Gary	MATH 107: Pre-Calculus	MATH 107: Pre-Calculus	MATH 171: Calculus I
Henry	Did not take	MATH 171: Calculus I	

Table 3: Mathematics Placement Based on Placement Test Performance

Before ENGR 107 some of the students expressed concern about their initial mathematics placement scores. One such student is Evan, who acknowledged that the placement score lowered his confidence and later described how he felt disappointed with what he had learned in high school providing a typical negative mastery experience.

Interviewer: If you had to rate your math ability on a scale from one is the lowest to ten is the highest, where would you rank and why?

Evan: Um, right now I'd probably rank it around 6 ish, just because I don't know, I don't feel like I was ready enough to take calculus just by the placement test so I'm not as confident as I normally would be…like if I got into calculus and I was up to par with some of my peers so yeah around 6 ish.

Interviewer: Hmm. So the placement test probably dropped you down a little bit?

Evan: Yeah. Like I thought I was doing pretty good for I don't know my level of math…as my age or my grade level till I took the placement test and couldn't get into calculus so.

Like Evan, Gary talked about how he "just didn't do well on the exam [placement test]". Gary, like other students, had taken calculus in high school and was taking ENGR 107 primarily to increase his placement score and get into calculus. Every student mentioned increasing their placement test scores or getting into calculus as a reason for taking the class. Most felt that without starting in calculus, they would be "behind" and sought to rectify that.

After students had a chance to retake the placement test, their feelings were very different, as many of them were quite successful; six out of eight placed into calculus. Evan, who was one of the students to take the placement test three times, described his reactions to the scores with the following.

Interviewer: Did an increased score on the placement test change your confidence?

Evan: Yes, it definitely changed my confidence. The first time raised it, but didn't raise it that much, just because I didn't get into Calc 171. But I got into 107, which was okay for me. After taking it a second time, I was really confident in my math skills. Because I think I scored 11 points more.

Christina, who only took the placement one time stated, "I scored an 81 on it and got into calculus, which I wouldn't be able to do without refreshing the material." Another student, Frank, expressed why he would recommend ENGR 107 to future students because of the placement test.

Interviewer: Would you recommend Engineering 107 to new students?

Frank: Definitely. Yeah, it was awesome. Great class. It helped me a lot.

Interviewer: In what ways?

Frank: It got me prepared for going into calculus again. It got me through the placement test good. I got a 68 the first time I took the placement test, and then I got a 79 after the class. So it helped me through that. That was perfect for what I needed it for.

Mastery experiences related to the ENGR 107 course were abundant and the majority of those identified in the study were positive. The frequency and positive nature of mastery experiences make them significant to student development of mathematics self-efficacy. Students generally gained positive mastery experiences by learning the material, obtaining desired grades, having a positive start to college, and by improved placement test scores.

ii. Vicarious Experiences

Vicarious experiences were another common factor affecting students' mathematics self-efficacy, although they were mentioned with less frequency than mastery experiences. Vicarious experiences tended to be more balanced than mastery experiences with both positive and negative experiences. Students often compared themselves to other students or even teachers, which led to both positive and negative vicarious experiences. These direct comparisons were the most frequently observed vicarious experiences. Another vicarious experience theme revolved around students perceptions of their academic standing compared to other students in the university. Many of the students came into ENGR 107 with the feeling that they were "behind", and that because they were not in calculus other students were better than them. Some felt that they were below other students because they had not taken high school calculus or that they had a weak mathematics background. These negative experiences morphed into positive experiences after the class when students felt that they were back on track.

Students' direct comparisons to others were abundant and had varied effects on students' mathematics self-efficacy. Most of the students felt that they were equal to or somewhat ahead of their peers. Students also demonstrated positive vicarious experiences by helping other students like Eldrick described during the mid-semester fall term interview.

> *Interviewer: How would you say you compare with your classmates in your math abilities, other people in your math class now?*
>
> *Eldrick: I think I'm pretty good. I was helping a few students the other day on a problem. There was a kid who was wondering if his answer was right. I'd double checked it like 3 times. I knew how to do this problem. I'd been doing it since 9th grade. I was obviously right. It's pretty easy.*

Here, he was confident because he was helping another student and felt that he was ahead of the other student in comparison. Similarly, David described an experience where he felt confident because he could use Microsoft Excel when other students could not.

> *Interviewer: Tell me about some experiences from 107 that helped you prepare for your current math class, or even other class you're taking.*

David: Yeah, I was going to talk about Engineering 120 right now. Because my Excel abilities are light years ahead of half the classroom. Before, I was bad at Excel. I wasn't very good.

Interviewer: That was very good self control (laughs)

David: No, like my tables are awesome now. Everyone's like, 'Dude, your tables are sweet.' And I'm like, 'Yeah, Engineering 107, man.'

Though many positive vicarious experiences were identified, there were also some negative ones. Students drew negative experiences when they compared themselves to other students or to teachers. Eldrick had a negative experience when he compared himself to one of the laboratory instructors in the following.

Interviewer: What experiences during class affected your confidence in math?

Eldrick: Um, I would say going home and…spending time on a problem for an hour, and I had no idea what to do. And then going into the lab and watching [the instructor] go through it, it seems so much easier. If I copy it down, I can remember from the day before what he was doing. I can try and do the problem like that, and it helps a little bit. It's still hard. He makes it look a lot easier than it is.

He was frustrated by the fact that he couldn't do the problem, but the instructor could make it look so easy. Eldrick is comparing himself to the instructor and since the instructor could do the problem he should have been able to as well. This would seem to be a common experience in the classroom because education is structured so the instructor is more knowledgeable than students. At the same time, this situation can lead to a valuable mastery experience if the student persists and is able to do the problem. Christina, on the other hand, had a negative vicarious experience when she compared herself to other students.

> *Interviewer: Do you perform well when there's noise or distractions around?*
>
> *Christina: Depending. Like today we did a study hall thing. It was lab, but it was really homework time. It was so awkwardly quiet and I didn't want to ask for help. Because I hadn't done this in so long, I don't even know the question I'm asking. It's going to sound ridiculous.*
>
> *Interviewer: So was anyone else asking questions?*
>
> *Christina: Not really. That's what made it awkwardly quiet. I'm like wow, everybody remembers this.*

She felt less confident because nobody asked any questions, making her feel like her questions would be "ridiculous". In this case, Christina thought she should know what was going on if everyone else understood it.

Students' perceptions of their academic standing elicited both positive and negative vicarious experiences. It was very common for students to feel like they were behind or not on track because they were not in calculus. Evan, like others, commented, "I was looking at the syllabus and it said you should be taking calculus freshman year so I guess I'm just trying to get to par I guess with what is expected." This is a sentiment that was felt by most students at the beginning of ENGR 107, with improving their mathematics placement scores being a high priority. By the end of ENGR 107, these feelings had largely become positive. Students felt that they had a jump or head-start on other students coming to college. Henry and Frank provided good examples of this change in their interviews at the end of the course.

Interviewer: Do you think this class has helped you prepare for college math classes?

Henry: Probably.

Interviewer: What makes you say that?

Henry: Because I reviewed. I'm a step ahead of everyone else. So they got 3 months with no math, and I got right into math and calculus. So I should be a step ahead.

Interviewer: What about compared to all the entering freshman at WSU?

Frank: Um, with this class I bet I would probably be more than average. Because I'm fresh in it. I'm not fresh out of summer and forgetting everything now. It's all fresh in my mind and ready to go. My confidence level is up.

Christina, like other students, felt that she was behind in math before ENGR 107, but after felt like she was on the same level as other students at the university. Feeling average or above average could easily mark an improvement in one's confidence.

Interviewer: How do you think you compare to the rest of the new students at WSU?

Christina: Um, I think definitely after this class it's brought me back like up to par with a lot of kids. I understand that a lot of kids in calculus are going to be like already well versed in a lot of the calculus that we'll be exposed to, but…I wouldn't have even had the derivative stuff we did this week if I hadn't taken the class.

While vicarious experiences were both positive and negative, the ENGR 107 course seemed to increase students' mathematics self-efficacy through vicarious experiences and changed students' previously held beliefs that they were behind. It is also useful to understand that negative vicarious experiences can arise from traditional academic structure when students compare themselves to educators.

iii. Social Persuasions

Social persuasions can be an important factor relating to the formation of mathematics self-efficacy beliefs, but they were not very well represented in this study. The most common or frequent social persuasion experiences were mentioned by students in the first interview relating to family members or friends. This is in line with Bandura, who said that social persuasions are evoked by "significant others" (1997, p. 101). Zeldin and Pajares found that significant others, especially family, play a major role in the way that women develop mathematics self-efficacy beliefs (2000). Social persuasions were only mentioned in the first interview, and no experiences were mentioned with regard to the ENGR 107 course.

Although no social persuasions related to ENGR 107 were observed, social persuasions from friends and family can be powerful influences. In the following quotation, Frank describes how social persuasions from his friends affected how he felt about himself.

Interviewer: How would your friends describe you in math?

Frank: Most of my friends would say I'm a genius just because I got into calculus and they're still in Algebra 1. But a lot of my friends that were in the same classes that I was, at the same level…probably middle of the road. A lot of my friends that were in the classes I was would come to me for help just like I would come to them. Some would come to me more than others. But again, I would go to smarter friends that I had. So kind of, not super smart but not the dumb kid type of deal.

Interviewer: Does it make you feel…does that change your ability, how you feel about your ability…knowing that some of your friends are like, 'wow, he can do calculus'…?

Frank: Yeah. It definitely is encouraging, and it's good to hear that, 'wow, you got into calculus. You must be smart, you made it through that class.' Of course that feels good.

Another student, David, received positive social persuasions regarding his mathematics abilities from his family.

Interviewer: Does your family ever talk about how you are in math? They think you're good at it or…?

David: Yeah. They, they always, whenever somebody asks what my strongpoint is, they'll say its math.

Interviewer: Huh. Does that affect how you feel about your abilities in math?

David: I…feel better about my abilities 'cause you know it's the only thing my dad will ever admit I'm good at.

David's dad seems to have had a major effect on the way David views his math abilities. Since his dad doesn't often admit that David is good at something, the fact that he said David is good at mathematics is that much more meaningful. David showed further that his dad can have a big influence on his confidence later in the interview.

Interviewer: How would you rate your confidence that you can succeed in college math courses?

David: Um, my dad actually said that if I show up to class and do the homework then…college is not much harder than high school is. And when he said that, I kind of got in my mind that I can do it. So I feel confident.

Here, David felt confident because his dad convinced him that he could do it. As can be seen from the previous examples, social persuasions were influential when they came from someone close to the student. This may explain the lack of social persuasions relating to the ENGR 107 course. The course was short and students were new to the university. For educators to become close enough to students in a short time-frame to create strong social persuasions is highly unlikely. Students also came into the class not knowing each other, diminishing the possibility that they would influence each other through social persuasions. The results of this study provide indications that social persuasions can be important factors relating to mathematics self-efficacy, but that they were not a major outcome of ENGR 107 because of the short-term nature of the course and lack of personal connection between students and instructors.

iv. Physiological States

Physiological states are hard to gauge in regard to mathematics self-efficacy. They change rapidly and are extremely variable. A person may be nervous for one test, but excited for another. To accurately measure and obtain these feelings and their effects on mathematics self-efficacy would require a different approach to data collection than was taken in this study. Because of this, physiological states were not a major goal of this study, though questions regarding them were asked. There were a few instances that students demonstrated the importance of physiological states. However, these were not in relation to the ENGR 107 course and did not demonstrate that students' mathematics self-efficacy beliefs had changed as a result. The first quotation is from Adam demonstrating how tests made him nervous, a negative physiological state, while the second is from David who had a positive physiological state relating to tests.

Interviewer: Do you perform well in math when you're being timed?

Adam: No.

Interviewer: OK. So you don't like exams at all

Adam: No.

Interviewer: Why is that?

Adam: It's nerve wracking, I guess.

Interviewer: OK. Do you always get nervous when you have exams?

Adam: Yeah, all exams.

Interviewer: Taking the test, you feel pretty good usually?

David: Yeah…I like taking tests. I like to show what I know, what I've learned and stuff.

…

David: Yeah. It's fun. It's like a contest or something.

These two students demonstrate how physiological states can be either positive or negative. In this case, David would clearly have had an increase in mathematics self-efficacy because of his physiological state, whereas Adam would most likely have had a decrease. Physiological states may play a role in building mathematics self-efficacy, but this study provided no evidence that these physiological states enacted any change in students' mathematics self-efficacy beliefs.

C. Discrepant Findings

There was one student who deviated from the norm and showed a decrease. Adam's mathematics self-efficacy, as reported by Part II of the survey, decreased by just under a point over the course of the class. Interestingly, Adam's reported mathematics self-efficacy on Part I, the problems subscale, increased while it decreased related to the college mathematics courses. Reviewing the interview transcripts provided some insight into possible reasons for this discrepancy. In the following quote, Adam describes how he felt after taking the ENGR 107 course.

Interviewer: Do you feel like you were successful in Engineering 107?

Adam: Uh, kind of. For the first 2 weeks. And the 3rd week it was kind of tough.

Interviewer: Why is that?

Adam: I'd never seen the equations before.

Interviewer: Oh really? Do you think it was kind of hard how they were presented in lecture, or…?

Adam: I don't know. It was just, if I had a little more time then it would be all better.

Adam talked about how the beginning of ENGR 107 was very helpful because it was material that he had seen before, but had not yet mastered. The course allowed him the chance to review and reinforce those ideas and concepts. The last week of the course was new material from calculus, which was too much too fast. During the interview, he talked about how his background in mathematics was weak and that he felt he was below average compared to other students in ENGR 107. Prior to ENGR 107, the highest mathematics course he had completed was high school pre-calculus. Four of the eight students in the course had taken calculus in high school, while, like Adam, the others had taken pre-calculus or an equivalent. His initial mathematics placement score would have put him into remedial math, unlike his counterparts who placed into college algebra or higher. Because of his comparatively weak background, Adam was a special case. Adam admitted that he was nervous about the mathematics courses he would be taking and felt that he was still somewhat behind. Adam's interview comments help to explain his abnormal survey results. His confidence was diminished with new and unfamiliar material, which could help to explain why his reported mathematics self-efficacy towards college mathematics courses might decrease. He was, however, very positive about how ENGR 107 helped him review and build mathematics skills. During the interview, Adam stated that his confidence in mathematics had increased, contradicting the survey itself.

VII. Implications for Educators

The results of this study provide information that can be useful for developing curriculum and improving teaching methods. This study demonstrates how students' can build and maintain increased levels of mathematics self-efficacy as the result of a college course.

Mastery experiences are one area that educators could build upon. Educators should strive to provide opportunities for students to be successful and gain valuable mastery experiences. These experiences are especially important for students in remedial mathematics or perceive themselves to be behind in mathematics, as indicated by Hall and Ponton (2005). They found that "Calculus I students exhibited a higher mathematics self-efficacy than the Intermediate Algebra students" (Hall and Ponton, 2005, p. 28) and concluded that in lower level math courses, educators should strive to increase these students' mathematics self-efficacy. Pajares (1996) had similar conclusions after studying mathematics self-efficacy beliefs of gifted students compared to regular students. Many of the students in ENGR 107 felt that they were behind in mathematics because they did not start in calculus. By the end of the course, students had improved both their abilities and their levels of confidence. If students in courses like this are given opportunities to gain valuable mastery experiences and increase their mathematics self-efficacy beliefs, educators may be able to keep them interested in mathematics related careers and also help them be more successful in future coursework.

Another area that educators could focus on is decreasing negative vicarious experiences. As described earlier, students may have negative vicarious experiences when they see an instructor make something that they were unable to figure out look easy. This can be harmful to the student's mathematics self-efficacy beliefs and should be avoided. Educators need to monitor these interactions. At the same time, struggle can be a very good learning experience as demonstrated by students who had significant mastery experiences when they "figured it out". Knowing how students learn and interpret experiences can be very useful information for educators.

After reviewing the data and course results, a number of specific suggestions can be made for increasing students' mathematics self-efficacy beliefs, while improving the overall effectiveness of the ENGR 107 course. These suggestions are specific to the course used in the present study, but may be useful in other courses as well. The class structure is something that appeared to be very beneficial. Students were appreciative of the fact that they came to college three weeks early. They were able to learn the ropes of college and get a feel for campus life, which they otherwise wouldn't have had. Having a small class size and a high teacher to student ratio both in lecture and lab is something that should be continued. Students were able to gain valuable mastery experiences during the course, many of which came from close interactions with instructors and the material. Homework and laboratory time where students are able to work closely with instructors allows them to learn concepts, ask questions, and feel more comfortable with that material. As previously stated, educators need to reduce negative vicarious experiences. Instructors doing problems in class with students is one strategy to accomplish this. As done in ENGR 107 as much as possible, instructors would solve a problem for the class using students' input to guide the process. This makes enhances the students' interaction with the lessons, as opposed to purely watching the instructor go through the motions.

VIII. LIMITATIONS

While this study was conducted with rigor and reliability as high priorities, some limitations do exist. First, is the small sample size. Having only eight students enrolled in the course resulted in having a limited data set. There was no way to sample or generalize the students that participated. Though the available amount of data was limited, that is not to say that the results are not important or suggestive. Another limitation was the lack of information regarding physiological states. The study was designed with the goal of determining the longitudinal effects of the course. The study's design and methods made collection of data relating to physiological states unlikely. To collect the type of data to examine these experiences would have taken a different study approach, which is something that is a suggested avenue for future research. Another potential limitation, as with much research, was that the participants might have responded in a way they thought would help the research or a way they thought was expected. Known as social desirability bias, since the students knew they were being studied for change, they may have inadvertently reported false change. This was part of the basis for multiple methods and instruments. The surveys and interviews yielding similar results provides reliability to the study. Other longitudinal self-efficacy research found that students actually minimize the amount of change through quantitative measures (O'Brien et al, 2000; Perry et al, 2007). Like all research, this study has its limitations, but these limitations were minimized to the greatest possible extent to provide useful and interesting results.

IX. Conclusions

Throughout the course of this study, students clearly demonstrated that their mathematics self-efficacy had increased throughout the duration of the ENGR107 course and that those beliefs could be sustained during the first semester of college. Mastery experiences were the most frequently described factor contributing to this increase and were largely positive experiences. It is believed that the increases in mathematics self-efficacy can be partially attributed to the ENGR 107 course itself. Quantitative surveys provided statistical evidence of the change, while the qualitative interviews provided in-depth experiences. Results from both methods indicate that ENGR 107 did, in fact, increase the mathematics self-efficacy of the students enrolled.

This research provides further evidence to support the four sources of self-efficacy proposed by Bandura (1997) and gives insight into how mathematics self-efficacy beliefs can change over time. Although this study provides solid evidence and one example, future research is needed to validate the longitudinal effects of a mathematics course on students' self-efficacy beliefs. Studies with larger sample sizes could allow for determination of statistical significance in the quantitative data. Because the students in this study were essentially isolated from outside experiences, future research could focus on courses that are taught while students are also involved with other courses and examine how effects of such a course are affected by outside influences. Future research designs might also incorporate methods to obtain information on physiological states related to coursework.

The results of this study indicate the fact that college courses and faculty have the ability to substantially affect the mathematics self-efficacy beliefs of their students. Knowing how valuable mathematics self-efficacy can be, educators can use this knowledge to provide a more meaningful and educational experience for the students.

X. References

Adelman, C. 1998. "Women and Men of the Engineering Path: A Model for Analyses of Undergraduate Careers". U.S. Department of Education Report: 1-105.

Bandura, A. 1997. Self-Efficacy: The exercise of Control. New York: W.H. Freeman and Company.

Betz, N.E. and G. Hackett. 1993. Manual for the Mathematics Self-Efficacy Scale. Redwood City: Mind Garden.

Betz, N.E. and G. Hackett. 1983. The Relationship of Mathematics Self-Efficacy Expectations to the Selection of Science-Based Majors. *Journal of Vocational Behavior* 23: 329-345.

Chemers, M., L. Hu, and B. Garcia. 2001. Academic Self-Efficacy and First-Year College Student Performance and Adjustment. *Journal of Educational Psychology* 93(1): 55-64.

Coyle, N. 2001. Why Math Careers? Women's Self-Efficacy Beliefs. Paper Presented at the *Annual Meeting of the Louisiana Educational Research Association*, Baton Rouge, LA, March 2001.

Gore, P. 2006. Academic Self-Efficacy as a Predictor of College Outcomes: Two Incremental Validity Studies. *Journal of Career Assessment* 14(1): 92-115.

Hagedorn, L., M. Vali Siadat, S. Fogel, A. Nora, and E. Pascarella. 1999. Success in College Mathematics: Comparisons Between Remedial and Nonremedial First-Year College Students. *Research in Higher Education* 40(3): 261-284.

Hall, M. and M. Ponton. 2005. Mathematics Self-Efficacy of College Freshman. *Journal of Developmental Education* 28(3): 26-32.

Hodges, C. and P. Murphy. 2009. Sources of Self-Efficacy Beliefs of Students in a Technology-Intensive Asynchronous College Algebra Course. *Internet and Higher Education* 12: 93-97

Hutchison-Green, M.A., D. Follman, and G. Bodner. 2008. Providing a Voice: Qualitative Investigation of the Impact of a First-Year Engineering Experience on Students' Efficacy Beliefs. *Journal of Engineering Education* 97(2): 177-190.

Klingbeil, N., R. Mercer, K. Rattan, M. Raymer, and D. Reynolds. 2005. Work in Progress-The WSU Model for Engineering Mathematics Education. *Proceedings 2005 Frontiers in Education Conference*, Indianapolis, IN, October 2005.

Klingbeil, N., K. Rattan, M. Raymer, and D. Reynolds. 2005. The WSU Model for Engineering Mathematics Education. *Proceedings 2005 ASEE Conference and Exposition*.

Kranzler, J. and F. Pajares. 1997. An Exploratory Factor Analysis of the Mathematics Self-Efficacy Scale-Revised. *Measurement & Evaluation in Counseling & Development* Vol. 29 Issue 4: 215-229.

Lent, R., S. Brown, and K. Larkin. 1984. Relation of Self-Efficacy Expectations to Academic Achievement and Persistence. *Journal of Counseling Psychology* 31(3): 356-362.

Lent, R., F. Lopez, and K. Bieschke. 1991. Mathematics Self-Efficacy Sources and Relation to Science-Based Career Choice. *Journal of Counseling Psychology* 38(4): 424-430.

Maag, M. 2004. The Effectiveness of an Interactive Multimedia Learning Tool on Nursing Students' Math Knowledge and Self-Efficacy. *CIN: Computers, Informatics, Nursing* 22(1): 26-33.

Mathisen, G. and K. Bronnick. 2009. Creative Self-Efficacy: An Intervention Study. *International Journal of Educational Research* 48: 21-29.

Miles, M. and A. Huberman. 1994. Qualitative Data Analysis: An Expanded Sourcebook. Thousand Oaks, CA: SAGE Publications, Inc.

O'Brien, K., L. Bikos, K. Epstein, L. Flores, R. Dukstein, and N. Kamatuka. 2000. Enhancing the Career Decision-Making Self-Efficacy of Upward Bound Students. *Journal of Career Development* 26(4): 277-293.

Pajares, F. 1996. Self-Efficacy Beliefs and Mathematics Problem-Solving of Gifted Students. *Contemporary Educational Psychology* 21: 325-344.

Pajares, F. and L. Graham. 1999. Self-Efficacy, Motivation Constructs, and Mathematics Performance of Entering Middle School Students. *Contemporary Educational Psychology* 24: 124-139.

Pajares, F. and D. Miller. 1995. Mathematics Self-Efficacy and Mathematics Performances: The Need for Specificity of Assessment. *Journal of Counseling Psychology* 42(2): 190-198.

Perry, J., D. DeWine, R. Duffy, and K. Vance. 2007. The Academic Self-Efficacy of Urban Youth: A Mixed-Methods Study of a School-to-Work Program. *Journal of Career Development* 34(2): 103-126.

Schulz, W. 2005. Mathematics Self-Efficacy and Student Expectations: Results from PISA 2003. *Annual Meetings of the American Educational Research Association*, Montreal, Canada, April 2005.

Schunk, D. 1981. Modeling and Attributional Effects on Children's Achievement: A Self-Efficacy Analysis. *Journal of Educational Psychology* 73(1): 93-105.

Schunk, D. 1991. Self-Efficacy and Academic Motivation. *Educational Psychologist* 26(3&4): 207-231.

Seymour, E. and N. Hewitt. 1997. Talking About Leaving: Why Undergraduates Leave the Sciences. Boulder, CO: Westview Press.

Teddlie, C. and A. Tashakkori. 2009. Foundations of Mixed Methods Research. Thousand Oaks, CA: SAGE Publications, Inc.

Usher, E. 2009. Sources of Middle School Students' Self-Efficacy in Mathematics: A Qualitative Investigation. *American Educational Research Journal* 46(1): 275-314.

Usher, E. and F. Pajares. 2009. Sources of Self-Efficacy in Mathematics: A Validation Study. *Contemporary Educational Psychology* 34: 89-101.

Walsh, A. 2008. The Relationship Among Mathematics Anxiety, Beliefs About Mathematics, Mathematics Self-Efficacy, and Mathematics Performance in Associate Degree Nursing Students. *Nursing Education Perspectives* 29(4): 226-229.

Zeldin, A. and F. Pajares. 2000. Against the Odds: Self-Efficacy Beliefs of Women in Mathematical, Scientific, and Technological Careers. *American Educational Research Journal* 37(1): 215-246.

APPENDIX A: INTERVIEW PROTOCOLS

1ST INTERVIEW PROTOCOL

1. Tell me about ENGR 107.
    - What do you know about this course?
    - Why did you choose to take this course?
    - What do you expect as a result of taking this course?
    - What would you have to do to consider yourself successful in ENGR 107?
2. Tell me a little bit about your math background.
    - What schools have you previously attended? [High school, CC, transfer, etc.]
    - What math courses have you previously taken?
    - Do you feel comfortable about these classes and the material you covered?
    - Tell me about the grades you typically receive in math. Would you say that they accurately reflect your abilities in math?
    - What sort of study habits do you have in math?
    - Under what conditions do you perform well in math? Under what conditions do you perform less well? Why?
        - Do you perform well in math when you are timed?
        - Do you perform well when there is noise or distractions?
        - Are there certain teaching or classroom styles that help you perform better?
    - How do you feel when you are given a math assignment?
    - When you are given a math test, how does that make you feel?
    - If you were asked to rate your ability in math on a scale of 1 (lowest) to 10 (highest), where would you be? Why?
    - Similarly, how would you rate your *confidence* in math? Why?
3. Let's talk about some of your experiences with math and school.
    - What would you say is your best subject? Why? What about your weakest subject?
    - What would you say is your favorite subject? Why? What about your least favorite?
    - Tell me about a class that you felt *confident* in your ability to perform the tasks you were given.
        - What class are you thinking of?
        - What comes to mind when you think about this class?
        - How does this class compare to your math classes? (if it's not a math class) What is different? What is the same?
    - Tell me about a time you experienced a setback in math. How did you deal with it?

- Describe the best teacher you've had in math. What made him (or her) so good? What about the worst teacher?
- What have your teachers told you about how you are in math?
    - Did that change how you feel about your ability in math?
- Tell me about your family and math.
    - How do they feel about math?
    - Do they use math in their lives?
- What has your family told you about how you are in math?
    - Did that change how you feel about your ability in math?
- How do your friends feel about math?
    - How do they do in math?
    - What do they say about it? What do they say about those who do well?
    - How would they describe you in math?
- What have your friends told you about how you are in math?
    - Did that change how you feel about your ability in math?

4. How do you feel about your upcoming college math courses?
    - How would you define success in math courses?
    - How would you rate your confidence that you can succeed in college math courses?
    - Do you think you will be more or less successful than other students at WSU in your math classes? Why?
    - What could make you feel more confident about yourself in math?
    - How do you think you will use math in your work or outside of work throughout your life?
5. How do you think ENGR 107 will affect how you feel about math?
    - Do you think that you will be more comfortable and less stressed about math after taking ENGR 107?
    - Do you think ENGR 107 will help you be more confident? Why or why not?
    - Do you think that taking ENGR 107 will help you be or feel more successful in math?
6. Here are just a few more wrap-up questions.
    - Do you have an intended major? If so, what is it?
    - How old are you?
    - [Note gender somewhere]

2ND INTERVIEW PROTOCOL

Mathematics and ENGR 107:

- Tell me about your experiences in ENGR 107.
    a. Do you feel that you were successful in the class?
    b. After taking this class, would you say your confidence in math has increased, decreased, or remained unchanged? On a scale of 1 to 10, how would you rate your confidence in math?
    c. What experiences have affected your confidence in math? How and why?
        - Are there any other factors or influences?
    d. Do you think this class has helped prepare you for math classes in college? Why or why not?
    e. Tell me about some positive aspects of the class.
    f. Tell me about some negative aspects of the class or about things that could have been improved.
    g. Would you recommend ENGR 107 to other students? Why or why not?
- How would you say you compare to the rest of your classmates in your math abilities? How about to the rest of the students entering college at WSU?
- How did you feel after retaking the Math Placement Test?
    a. Do you think you did better or worse than your previous results?
- What math class are you planning on taking during the fall semester?
    - Tell me about your feelings towards this upcoming class.
    - Do you feel that you will be successful? Why or why not?
    - What experiences do you feel you have had that helped prepare you for this class?
- If you were asked to rate your ability in math on a scale of 1 to 10, where would you be? Why?
- How would you rate your confidence? Why? Would you say that ENGR 107 has helped your confidence in mathematics? Why or why not?

3RD INTERVIEW PROTOCOL

- What math class are you currently in?
    a. How is that class going for you?
    b. Is it what you expected when you started?
    c. Tell me about some of your experiences in that class.
    d. Tell me about some of the positive and negatives.
    e. How does this class compare to ENGR 107?
    f. How would you define success in this course?
    g. Do you think you will be successful in this course?
    h. Do you think that ENGR 107 helped you to be more successful in this class? Why or why not? Confident?
    i. Tell me about some experiences from 107 that helped prepare you for this class.
    j. Do you think you can be successful in future math and engineering courses?
        a. Why do you think that?
        b. Was ENGR 107 helpful for this?
- If you were asked to rate your ability in math on a scale of 1 to 10, where would you be? Why?
- How would you rate your confidence? Why? Tell me about how ENGR 107 has affected your confidence.
- How would you say you compare to the rest of your classmates in your math abilities? Now that you have experienced college math,
- Tell about the whether or not you think it was beneficial to take ENGR 107.
- Would you recommend ENGR 107 to other students? Why or why not?
    - (if yes) Tell me about how we could best encourage people to take it.
    - What would you tell somebody who was in your position?
    - What would you tell somebody it will do for their confidence?
- Tell me about some positive and negative aspects of the class.
- Are there things that could be improved about ENGR 107?
- Do you have any questions?
- Is there anything that you would like to add that we have not covered?

Generic topics (if not already brought up)

I. How was having lab right after class? How does that compare to class right now?
II. Was it beneficial to start on a good foot? Get a good grade in 107? What if you hadn't done well?
III. Was it helpful to be on campus? Get a routine?
IV. Was it a problem to have class 3 weeks before fall semester? Did it cut into summer?

APPENDIX B: SURVEY PROTOCOLS

Score: ________________

Please provide the following information:

WSU ID Number: ________________________

Date: ______________ Age: ________ Gender (Please Circle): **F** **M**

Year in College: ________________________

Highest Math Course Completed: _____________________________________

Intended Major: _________________________________

Part I: Mathematics Problems

Please indicate how much confidence you have that you could successfully solve each of these problems by circling the number according to the following 10-point confidence scale.

Confidence Scale:

<u>No Confidence at all</u> **<u>Very little Confidence</u>** **<u>Some Confidence</u>** **<u>Much Confidence</u>** **<u>Complete Confidence</u>**

0 1 2 3 4 5 6 7 8 9

Example: How much confidence do you have that you could successfully solve:

91. If $x + 7 = 3x - 4$, what does x equal? **0 1 2 3 4 5 6 7 8 9**

If your response on the 10-point continuum was #5, "Some Confidence", you would circle the number 5 next to question #91 like so:.

91. If $x + 7 = 3x - 4$, what does x equal? **0 1 2 3 4 (5) 6 7 8 9**

Now turn to the next page and begin Part I. Be sure to answer every item.

WSU ID Number: ________________

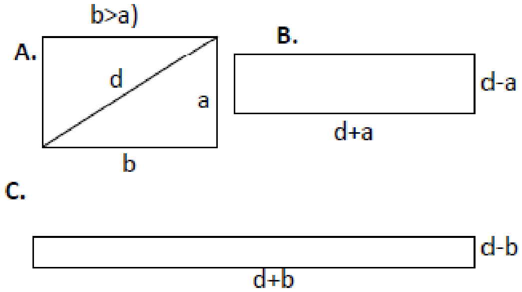
Part I

No Confidence at all	Very little Confidence	Some Confidence	Much Confidence	Complete Confidence
0	1 2 3	4 5	6 7	8 9

How much confidence do you have that you could successfully solve:

1. In Starville, an operation *o* on any numbers a and b is defined by a*o*b = a x (a + b). Then 2*o*3 equals ____?____. **0 1 2 3 4 5 6 7 8 9**

2. Sally needs three pieces of poster board for a class project. If the boards are represented by rectangles A, B, C, arrange their areas in increasing order. (assume b>a) **0 1 2 3 4 5 6 7 8 9**



3. The average of three numbers is 30. The fourth number is at least 10. What is the smallest average of the four numbers? **0 1 2 3 4 5 6 7 8 9**

4. To construct a table, Michele needs 4 pieces of wood 2.5 feet long for the legs. She wants to determine how much wood she will need for five tables. She reasons: 5 x (4 x 2.5) = (5 x 4) x 2.5. Which number principle is she using? **0 1 2 3 4 5 6 7 8 9**

Go on to next page.

WSU ID Number: ________________

Part I (Cont.)

<u>No Confidence at all</u>	<u>Very little Confidence</u>	<u>Some Confidence</u>	<u>Much Confidence</u>	<u>Complete Confidence</u>
0	1 2 3	4 5	6 7	8 9

How much confidence do you have that you could successfully solve:

5. The opposite angles of a parallelogram are ________.	0	1	2	3	4	5	6	7	8	9
6. Five points are on a line. T is next to G. K is next to H. C is next to T. H is next to G. Determine the relative positions along the line.	0	1	2	3	4	5	6	7	8	9
7. There are three numbers. The second is twice the first, and the first is one-third of the other number. Their sum is 48. Find the largest number.	0	1	2	3	4	5	6	7	8	9
8. In a certain triangle, the shortest side is 6 in., the longest side is twice as long as the shortest side, and the third side is 3.4 in. shorter than the longest side. What is the sum of the three sides in inches?	0	1	2	3	4	5	6	7	8	9
9. The hands of a clock form an obtuse angle at ______ o'clock.	0	1	2	3	4	5	6	7	8	9
10. Bridget buys a packet containing 9-cent and 13-cent stamps for $2.65. If there are 25 stamps in the packet, how many are 13-cent stamps?	0	1	2	3	4	5	6	7	8	9
11. A living room set consisting of one sofa and one chair is priced at $200. If the price of the sofa is 50% more than the price of the chair, find the price of the sofa.	0	1	2	3	4	5	6	7	8	9

Go on to next page.

WSU ID Number: _______________

Part I (Cont.)

No Confidence at all	**Very little Confidence**			**Some Confidence**		**Much Confidence**		**Complete Confidence**	
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

How much confidence do you have that you could successfully solve:

12. Write an equation which expresses the condition that "the product of two numbers R and S is one less than twice their sum."	0	1	2	3	4	5	6	7	8	9
13. Set up the problem to be done to find the number asked for in the expression "six less than twice 4 5/6".	0	1	2	3	4	5	6	7	8	9
14. On a certain map, 7/8 in. represents 200 miles. How far apart are two towns whose distance apart on the map is 3 1/2 in.?	0	1	2	3	4	5	6	7	8	9
15. The formula for converting temperature from degrees Centigrade to degrees Fahrenheit is F = 9/5 C + 32. A temperature of 20° Centigrade is how many degrees Fahrenheit?	0	1	2	3	4	5	6	7	8	9
16. 3 3/4 - 1/2 =	0	1	2	3	4	5	6	7	8	9
17. If 3*x* - 2 = 16 - 6*x*, what does *x* equal?	0	1	2	3	4	5	6	7	8	9
18. Fred's bill for some household supplies was $13.64. If he paid for the items with a $20, how much change should he receive?	0	1	2	3	4	5	6	7	8	9

Go on to Part II.

WSU ID Number: ________________

Part II: Math Courses

Please rate the following college courses according to how much <u>confidence</u> you have that you could complete the course with a <u>final grade</u> of "A" or "B". Circle your answer according to the 10-point scale below:

No Confidence at all	Very little Confidence			Some Confidence		Much Confidence		Complete Confidence	
0	1	2	3	4	5	6	7	8	9

19. Basic College Math..................0 1 2 3 4 5 6 7 8 9
20. Economics 0 1 2 3 4 5 6 7 8 9
21. Statistics 0 1 2 3 4 5 6 7 8 9
22. Physiology 0 1 2 3 4 5 6 7 8 9
23. Calculus 0 1 2 3 4 5 6 7 8 9
24. Business Administration 0 1 2 3 4 5 6 7 8 9
25. Algebra II 0 1 2 3 4 5 6 7 8 9
26. Philosophy...............................0 1 2 3 4 5 6 7 8 9
27. Geometry 0 1 2 3 4 5 6 7 8 9
28. Computer Science 0 1 2 3 4 5 6 7 8 9
29. Accounting 0 1 2 3 4 5 6 7 8 9
30. Zoology....................................0 1 2 3 4 5 6 7 8 9
31. Algebra I 0 1 2 3 4 5 6 7 8 9
32. Trigonometry 0 1 2 3 4 5 6 7 8 9
33. Advanced Calculus 0 1 2 3 4 5 6 7 8 9
34. Biochemistry 0 1 2 3 4 5 6 7 8 9

You have now completed the Mathematics Self-Efficacy Scale.
Thank you for your cooperation.