A CASE STUDY OF MATHEMATICS SELF-EFFICACY IN A FRESHMAN ENGINEERING MATHEMATICS COURSE

By

JACOB ROWLAND BURNHAM

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To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of JACOB ROWLAND BURNHAM find it satisfactory and recommend that it be accepted.

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Shane A. Brown, Ph.D., Chair

____

Robert G. Olsen, Ph.D.

____

Cara J. Poor, Ph.D.

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Abstract

by Jacob Rowland Burnham, M.S.
Washington State University
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Chair: Shane A. Brown

Student retention in engineering majors has become a cause for concern to the future of the science and technology industry in the United States. Researchers have since produced large bodies of evidence indicating a positive relationship between mathematics self-efficacy and students' choice of science-related educational and career pathways (Betz and Hackett, 1983; Hackett and Betz, 1989; Lent et al., 1991). This study examined the effects of an introductory math course grounded in engineering context on the mathematics self-efficacy of 27 college freshman with the intent to pursue engineering. Surveys and interviews conducted before and after the course were triangulated to identify consistent, inconsistent, and contradictory findings of efficacy change for each student. Students were grouped based on the similarities in efficacy experiences that they demonstrated in their responses to each method. Following pattern coding of interviews, group analysis was performed to identify, within each group, common mechanisms/sources of efficacy as dictated by Bandura's Self-Efficacy Theory. Results of a paired t-test analysis of a modified version of the Mathematics Self-Efficacy Survey (MSES) indicated a significant increase in students' math problem solving efficacy; however no significant change was observed for math courses efficacy. Results were congruent with previous research supporting that mastery experiences are the most powerful efficacy source; and was the only source common among students in each efficacy grouping. The most prevalent mastery experiences aggregated from the collection of group responses included: students' feeling prepared for calculus after having been exposed to introductory calculus material, learning that occurred through application of class examples to homework problems, correctly learning material that was misunderstood in previous math classes, and successful performance on the math placement test. Efficacy sources that were prevalent in each group and potential reasons for similarities and differences across groups are discussed.

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Dedication

This work is dedicated to my girlfriend Casey, my parents, and my sister for their belief and inspiration.

I. Introduction

In the United States, decreased retention within science, mathematics, and engineering majors has been an issue of widespread concern since the 1980's (Seymour and Hewitt, 1997). In order for the U.S. to remain competitive with other nations in the field of science and technology innovation, universities must be able to produce enough creative, able-minded college graduates in related fields to ensure U.S. advancement in science at the global level. The drastic increase in attrition has spurred researchers to focus on the problems with enrollment and persistence in engineering. Today, approximately 40% of the students who start out in engineering eventually change majors or do not finish college (Vogt, 2008). Furthermore, transfer of students from other majors to engineering cannot compensate for this high attrition rate in engineering, due in part to the specific course load that is predetermined for engineering students from the beginning of their freshman year (National Science Board, 2007). Focus on attrition in engineering has emphasized the beginning of students' engineering education as the time when decisions to stay or switch majors are made; it has been deemed the "primary period of risk", as it is the period before students have formally declared a major (Seymour and Hewitt, 1997).

The first two years of the engineering experience consist largely of challenging, strictly mathematics courses, generally beginning with calculus. The National Science Foundation has funded an initiative to develop a study to confront the mathematics bottleneck that has developed during the first year of traditional engineering curriculums (Klingbeil et al., 2005). Wright State University responded with the development of a course model for a freshman level engineering mathematics course, with the ultimate goal that "students can advance in the curriculum without having completed a traditional first-year calculus sequence." The implications of this course model are specific to the administrative decisions of the university implementing it; therefore as a part of its own specific considerations, Washington State University slightly modified the material created by Wright State University and integrated additional material that was considered pertinent based on the intentions of the course. The course (labeled as "Engineering 107-Introductory Math for Engineering Application") was designed as a "transition course" between high school and college level math, addressing topics of pre calculus and introductory topics of calculus, all within the context of engineering application problems. At WSU, ENGR 107 will only serve to prepare students to test into calculus, following which they will also receive exposure to introductory calculus topics to provide them with a familiarity with which to draw from when beginning calculus. To more deeply understand the effects of ENGR 107 on the retention of engineering students, this study will be addressed through the theoretical lens of self-efficacy. The decision behind this theoretical perspective stems from current research on self-efficacy and the potential for such findings to compliment the intentions of the NSF's study regarding retention; whereby students' perceptions of ability, or efficacy, may likely have much higher predictive utility than actual ability, with regard to educational pathway decisions (Hackett and Betz, 1989).

II. Theoretical Framework

A. Mathematics Self-Efficacy

Self-efficacy is a concept introduced by psychologist Albert Bandura, defined as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 3). He hypothesized four sources of self-efficacy, which include mastery experiences, vicarious experiences, social persuasions, and physiological and affective states. Mastery experiences include a person's interpretations of his/her past performances and are supported as the most powerful source of self-efficacy (Lent et al., 1991; Usher and Pajares, 2009). Vicarious experiences involve a person's interpretation of his or her performance in comparison to the performance of another individual and whether they conclude it to be a success or failure. Social persuasions are encouragements that a person receives from influential sources including peers, teachers, and parents. Lastly, physiological or affective states involve symptoms such as stress and anxiety that are stimulated as a result of a specific event or grouping of events. Together, these four categories have been publicly accepted as enveloping all observed means of influence on self-efficacy. Studies such as that performed by Hutchison-Green et al. (2008) on students' engineering self-efficacy have further validated this acceptance by intentionally seeking student responses that did not fall within the confines of one of the four sources, of which none were found.

In a study by Zeldin et al. (2008) comparing the factors that influenced the self-efficacy beliefs of successful men and women in STEM careers, physiological state was the only source that was not identified as a significant influence to their self-efficacy beliefs during their collegiate experiences. Men and women in STEM careers are an example of successful retention within science related majors, therefore the efficacy sources they promote are of direct relevance to improving retention in STEM majors. Consequently, accounting for physiological states is not within the scope of this study. This decision is based on the findings of Zeldin et al. (2008) and the specific reliance of physiological sources on cognitive associations between experience and emotion. Such associations are difficult to generalize, as they may differ vastly from person to person based on emotions rooted in unique individual life experiences.

Since its introduction, a multitude of research on self-efficacy has been conducted over the past 30 years, identifying it to be predictive of expectations and performance in first year college students (Chemers et al., 2001) and positively correlated with persistence of students in science and engineering (Lent et al., 1984). More specifically, researchers have used this theory to address the realm of *mathematics* self-efficacy, or a person's belief in their ability to successfully perform mathematics. Lent et al. (1991) discovered mathematics self-efficacy to indirectly affect science related career choice by directly influencing student interest. In other words, mathematics self-efficacy drives people's personal interests because people are more likely to perform tasks they believe they are capable of (Bandura, 1997). Therefore, mathematics self-efficacy is linked to choices of science related careers, as science careers involve a high degree of mathematics. Since students with higher mathematics self-efficacy are more likely to choose science based educational and vocational pathways (Betz and Hackett, 1983; Hackett and Betz, 1989; Lent et al., 1991), mathematics self-efficacy serves as a focal point from which to address retention in engineering and students' actions to stay within their chosen field.

In the engineering curriculum, calculus is generally identified as a first-year math course, yet over 40% of first-year college calculus students fail the course (Wieschenberg, 1994) and thus cannot advance in the mathematics portion of the engineering curriculum. Bandura (1997) postulates that if failures are experienced before one's sense of self-efficacy is developed, the creation of positive self-efficacy beliefs can be difficult. The Wright State course model hopes to sidestep this initial negative experience on student mathematics self efficacy through a “transition course” from pre calculus to calculus (providing students successfully test into calculus), where prior experiences with perceived similarities to a new learning situation have been found to influence students’ learning efficacy (Schunk, 1989). This initiative to intervene in students’ initial college math experience is further supported by Gore (2006), who found that promotion of student efficacy beliefs was highly dependant on experiences during the first semester of college. It is the goal of this project that ENGR 107 will serve to better students’ foundational knowledge of pre calculus concepts and instill in them more confidence for beginning calculus. We believe this will provide students with a better opportunity to experience initial success in college mathematics and to create positive self-efficacy beliefs; for which research has shown students who enter college with more confidence perform better academically than less confident students (Chemers et al., 2001).

Bandura (1997) postulates that perceptions of self-efficacy are context specific, thus people possess different degrees of self-efficacy specific to the tasks required of them. Therefore, measures of self-efficacy must be analyzed with respect to a specific domain. With regard to retention in engineering, the positive correlation between mathematics self-efficacy and choice of science related major necessitates the need for studies addressing the specific domain of mathematics self-efficacy. More specifically, Schunk (1991) has advocated the need for research done in the class setting to understand the effects of teaching and learning on student efficacy. While research has since addressed student efficacy in classroom settings, expansion into the college setting has been minimal and of limited intent. Hall and Ponton

(2005) examined the effects of a calculus class and a developmental math class on the relative change of college freshman students' mathematics self-efficacy. Although this study identified changes in students' efficacy, it did not address *why* such changes occurred. In a contrasting study, Hodges and Murphy (2009) identified the most prominent sources impacting students' mathematics self-efficacy in an online college math class; however the extent of efficacy change was not addressed, nor were class-specific examples of identified sources discussed. There lies a gap between these two research endeavors that can be filled by a case study that simultaneously measures student efficacy change and associated mechanisms/sources of mathematics self-efficacy in a college math class.

In order to develop a well founded, theoretical model that exercises a complete understanding of mathematics self-efficacy, a sufficient body of diverse, applicable contextual experiences must first be gathered. Consequently, because efficacy source effects should not be generalized across settings (Usher and Pajares, 2009), analyzing the contributions of each context within this domain will help to determine if mechanisms/sources of mathematics self-efficacy are generally domain or context specific. For example, Usher (2009) found that within the domain of mathematics self-efficacy, there was a positive correlation between efficacy and student self regulatory practices in middle school math classes; however, research must be performed across many contexts within the domain of mathematics self-efficacy to confidently generalize across the entire domain and attempt to replicate such results. Research within the domain of mathematics self-efficacy has been applied over a variety of contexts, most of which lie specifically in the mathematical realm; although attempts have been made to study its effects in other contexts, such as nursing (Maag, 2004; Walsh, 2008). This study aims to fill a gap in the college setting of mathematics self-efficacy research, while also bridging that gap with a class grounded in engineering context math problems, which has never been studied with regard to mathematics self-efficacy.

The National Research Council's report on "How People Learn" (2000) dictates that "Reasoning can be improved when abstract logical arguments are embodied in concrete contexts" (p. 74) (Wason and Johnson-Laird (1972). Therefore ENGR 107 is intended to better prepare students for future engineering courses by addressing math topics in contexts that are prominent in courses throughout the engineering curriculum (Klingbeil et al., 2005). Furthermore, in their study on creative self-efficacy, Mathison and Bronick (2009) suggested that problems be presented in a "real world" context, as students feel it to be relevant to their field of interest. Although mathematics self-efficacy is the construct under examination, the students of ENGR 107 intend to pursue a degree in engineering; therefore presenting problems in engineering contexts may help increase their efficacy within their major, and the mathematics self-efficacy they associate with it.

Usher (2009) identified that specific, contextual influences, such as course placement, lend themselves to student efficacy development; the effects of such influences are the concern of this study. Based on the considerations that have been made for ENGR 107, we aim to answer the following questions:

1. In what ways and to what extent does participation in Engineering 107 impact students' math problem solving efficacy and math courses efficacy?

2. What are the prominent mechanisms impacting Engineering 107 students' mathematics self-efficacy, and how do they satisfy the source conditions dictated by Bandura's theory of self-efficacy?

This study is one of many that must take place in order to produce an accurate generalized model that encompasses the domain of mathematics self-efficacy. While this study is motivated by the need for a restructuring of the first-year engineering mathematics curriculum to increase retention in engineering, it also serves to advance our understanding of how efficacy operates in different contexts. Today there is still a need for research performed in classroom settings, as it is especially lacking in studies that explain class-specific causal agents of efficacy change and their relative impacts on students. The detailed focus on the phenomenon of mathematics self-efficacy and how it operates within the context of an engineering mathematics course classifies this research within a case study design (Yin, 2009). The information derived from this case study can provide a piece of the vast, critical puzzle that defines the nature of mathematic self-efficacy; operating as the inagural step towards engineering mathematics efficacy application.

B. Methodology

This study utilized both quantitative surveys and qualitative interviews administered before and after the course. The decision to use both quantitative and qualitative methods of analysis was reflective of the questions of the study, and likewise the chosen methods of previous studies employing the same theoretical framework. Quantitative methods have been solely and consistently used throughout mathematics self-efficacy research among large populations to quantify changes in efficacy (Hall and Ponton, 2005; Maag, 2004), relationships between efficacy and other motivational constructs on specific outcomes (Betz and Hackett, 1983; Hackett and Betz, 1989; Lent et al., 1991; Pajares, 1996; Pajares and Graham, 1999; Pajares and Miller, 1995), and relative impacts of the four hypothesized sources of self-efficacy (Hodges and Murphy, 2009; Lent et al., 1991;). However these methods are restricted by their numerical outputs, as they cannot depict *why* such changes occur. Researchers have since proclaimed the need for qualitative methods in future studies (Schunk, 1991; Pajares, 1996; Usher and Pajares, 2009). Qualitative methods have been less commonly used in mathematics self-efficacy research to vividly describe the mechanisms/sources that influence people's efficacy (Usher, 2009; Zeldin and Pajares, 2000; Zeldin et al., 2008); however, their interpretive nature limits their population size and has produced debate regarding their ability to generalize findings, as they cannot be objectively applied and replicated.

Although qualitative methods have been publicly accepted as accurate means of research, there use has sparked debate among the professional research community over what can be deemed as accurate. This debate stems from the historical construction of what "accuracy" means, which has been described using of concepts of validity and reliability; terms that were generated from the methodological standpoint of science-based quantitative research (Marshall and Rossman, 2011). However, as Sroufe (1997) states, "what education research cannot do is compete head to head with the intrinsic glamour of the engineering and biological sciences" (p.26). While the phenomena of study in hard sciences are constrained by such factors as material properties and physical laws, the variability of individual human cognitive interactions and interpretations cannot be constrained by quantitative definitions of accuracy. Educational research must therefore turn to equivalent measures of accuracy developed for social sciences and qualitative research. Postmodernist wave's of thought within social sciences have since questioned all attempts to gain validity, asking, "…if findings are constructions and truth a "mirage," aren't evaluative criteria also constructions and therefore subject to debate" (Corbin and Strauss, 2007, p. 297). Under this rationalization, although complete validity theoretically cannot ever be obtained, the only way to perform accurate and reliable research is to work towards the idea of complete validity by invoking as many established validity methods as possible that lie within the constrains of the study. This study will therefore employ the use multiple methods in order to triangulate the findings of each method to provide the most accurate interpretation of the social phenomena observed.

The simultaneous use of both quantitative and qualitative methods in mathematics self-efficacy research has been rare and to minimal extent (Walsh, 2008). While the sole use of only one methodology has been the historically common practice in this domain, the respective disadvantages of each method have long been voiced by quantitative and qualitative researchers alike. By employing a mixed methods approach, studies such as those performed by Perry et al. (2007) and O'Brien et al. (2000) have even identified inconsistent findings of efficacy change between the two methodologies. This is not to say that the use of mixed methods is inherently dominant over the use of one single methodology; but depending on a study's research questions, the strength of a mixed method design lies in it's ability to "simultaneously ask confirmatory and exploratory questions and therefore verify and generate theory in the same study" (Teddlie and Tashakkori, 2009, p. 33). For this study, asking "if and to what extent a change occurred" is a confirmatory question; whereas asking to understand "the mechanisms impacting ENGR 107 students' mathematics self-efficacy" and their placement within Bandura's efficacy sources is an exploratory question. By answering the confirmatory question we can attempt to verify the theory that ENGR 107 will promote retention in engineering. Identifying the mechanisms/sources in ENGR 107 will allow us to generate theory about their respective contributions to the changes in students' efficacy that were observed. Based on the research questions of this study, we will employ mixed methods procedures, including quantitative surveys and qualitative interviews, to provide a holistic accounting of the effects of students' participation in ENGR 107.

Triangulation of both methods will allow the quantitative and qualitative findings to be evaluated with regard to each other to facilitate an accurate data representation. Triangulation will thus invoke the following procedure, which is displayed in Figure 1 below (the specifics of each method are described in the "methods" section): first, pre and post quantitative surveys will be analyzed to determine if an efficacy change occurred among the students as a single population. However, the case study research design dictates that a microanalysis of individual student changes must also be performed in order to triangulate students' results with evidence from their pre and post qualitative interview findings (Yin, 2009); determining if, and to what extent, a change in mathematics self-efficacy occurred for each student as a result of ENGR 107. Students will be categorized into groups based on similar efficacy experiences via triangulation of both methods, after which the interviews alone will be examined to identify common mechanisms/sources among the students in each group. Background commonalities will also be assessed and, wherever applicable, presented for the purpose of further explaining students' experiences in the class. From this procedure we aim to address the challenge proposed by Bandura (1997) by identifying mechanisms within the established efficacy sources that have resulted in different efficacy developments among the ENGR 107 students.

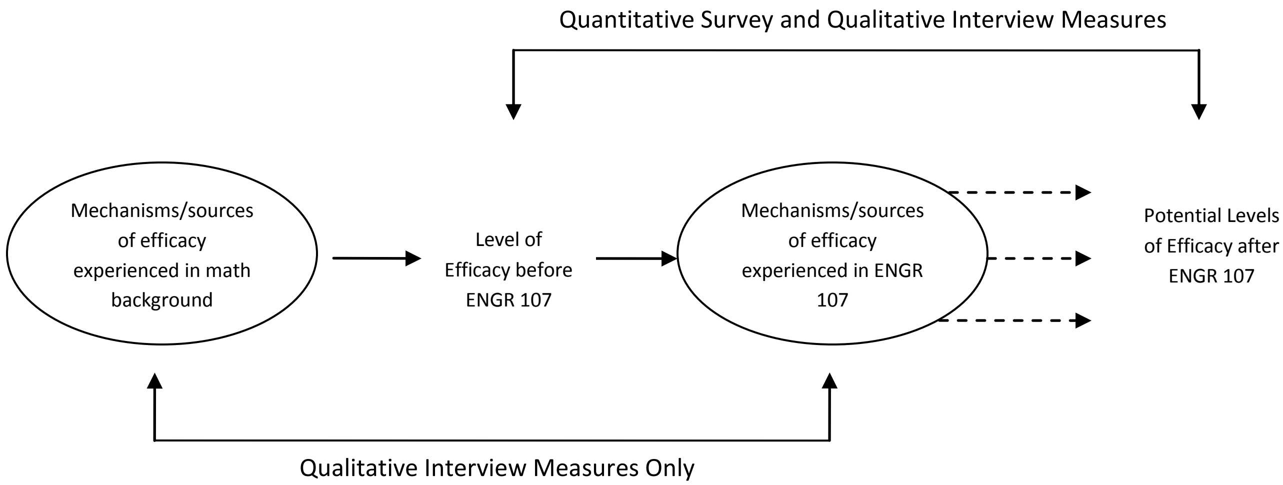

Figure 1-Mixed Methods Procedure

III. Class Details and Eligibility

Initially, Washington State University offered ENGR 107 as a three week summer course during 2009 which enrolled 8 students. The summer implementation served as a trial version of the course, studying the effects of the course on the mathematics self-efficacy of the participating students (Barker, 2010). After observing initial success in the course, in which 6 of the 8 students who were initially placed into pre-calculus or a lower math course placed into calculus after ENGR107 through a math placement exam, the course was adapted to the fall schedule and taught in the fall of 2010. The focus of this study is strictly the fall implementation of ENGR 107.

Eligibility for ENGR 107 was determined based on the university math eligibility requirements for Math 107- Pre calculus, from the highest score of student SAT, ACT, and

ALEKS math placement scores. ENGR 107 enrolled 27 students, four of whom had no prior exposure to pre calculus and half of whom had been exposed to calculus in high school but tested at a pre calculus level. Although the class was designed for students who had previously experienced pre calculus, exceptions were made for students that placed higher but who felt more comfortable in taking a "refresher" course before attempting college level calculus, as well as for students who placed slightly lower than at the pre calculus level. Enrollment was limited to students pursuing engineering, but did not distinguish between specific disciplines within engineering. In all cases, every effort was made by the engineering academic coordinators to correctly place students with adequate preparation into ENGR 107.

ENGR. 107 was structured to consist of two 1-hour lecture periods and one 3-hour lab period per week. The first 10 weeks of the 15 week course were dedicated to teaching pre-calculus concepts, including basic algebra operations, exponents, radicals, exponential and logarithmic functions, linear and quadratic equations, graphing functions, trigonometry, 2D vectors, systems of equations, and a brief introduction to sinusoids. The remaining 5 weeks of the course focused on introducing students to calculus concepts of derivatives and integrals to provide a smooth transition for students in preparation for calculus the following semester. The class was aimed to provide students with significant amounts of engineering context example problems and promote more opportunities for active learning than a strictly lecture-based math class.

The labs were arranged for the students to experience hands on application concurrent with the concepts they were learning in the lecture period of a given week. The labs consisted of six "application labs" (Table 1-1) and three "ALEKS labs." ALEKS is an online learning program that supplies instructors with resources to assign homework, quizzes, tests, and monitor student progress and areas that are in need of improvement and is an intelligent testing system used for math placement at WSU. The ALEKS labs were designed to increase students' familiarity with the workings of the program and provide them with practice problems relevant to the course topics covered prior to each lab. The ALEKS placement test has become a standard for math eligibility at Washington State University and was therefore required of ENGR. 107 students to determine their math placement for the following semester. After 10 weeks in the class the pre calculus concepts were fully covered and the ALEKS placement test was administered to the students. The students who did not place into calculus were given the option to retake the exam the following week. Students failing to test into calculus were required to enroll in a math course based on university enrollment criteria for the following semester.

Table 1-1 – Laboratory Topics

Lab 1-Exponential Growth and Decay	Sampling performed to model exponential growth; Basic cell and graphing functions of Excel
Lab 2-Application of Algebra in Engr.	Measuring current, voltage, and resistance in multiple circuits; Linear and parabolic equations
Lab 3-Application of Trigonometry in Engr.	One-link and two-link robots; Right triangle properties; Law of sines/cosines
Lab 4-Statics	2D vectors; Systems of equations
Lab 5-Freefall Application of the Derivative	Relationship of position, velocity, and acceleration; Theoretical versus measured values
Lab 6-Spring Work Application of the Integral	Concepts of work and energy

IV. Methods

A. Ethical Consideration

As part of the effort to provide an accurate account of both the class and the interpretations of the results, I held the positions of instructor for the course and researcher for the project. Although seemingly similar at first, this study does not fall within the confines of practitioner research, which Anderson and Herr (1998) describe as research that uses knowledge that is specific to the researcher's experiences in their professional setting. The authors also identify the criticism of practitioner research that practitioners have an emotional involvement with their research, making it vulnerable to bias. In this study, efficacy, or a student's *belief about their own ability*, was the concept in question, and only accepted measures of analysis were invoked to satisfy the questions of the study. Therefore my lived realities were not involved in my interpretations of students' beliefs about there own abilities. Any emotional involvement I had is similar to the emotional involvement any researcher has with their work; this potential for bias was therefore a constant consideration during analysis and accepted methods of validity were used to assure accurate data representation. Special ethical considerations were afforded for both the interview process and protocol development, and will be addressed in those sections.

B. Quantitative Survey

This study utilized the Mathematics Self Efficacy Survey (MSES) developed by Betz and Hackett (1983). This survey was originally developed for the college setting and has been widely used throughout mathematics self-efficacy research. It consists of 52 questions within three efficacy subscales, including math problem solving, everyday math tasks, and math courses, for which students must respond by rating their confidence for each question on a Likert scale ranging from *no confidence at all* (0) to *complete confidence* (9). Both the full scale original survey and its subscales have been independently validated with coefficient alphas ranging from .72 to .96 (Betz and Hackett, 1983; Walsh, 2008). Revised versions of the MSES have also been tried and tested with coefficient alphas between .90 and .95 (Lent et al., 1991; Kranzler and Pajares, 1997; Pajares and Miller, 1995).

Researchers have stressed the importance that measures of self-efficacy be formatted specifically to the performance task they are addressing (Pajares and Miller, 1995; Kranzler and Pajares, 1997). Although it is important that the questions have relevance to ENGR 107 (including the algebra and geometry based problems addressed in the MSES), for the purpose of this study the MSES was not being used as a predictor, only as a relative measure of efficacy change; therefore by using the same survey before and after the class, it was determined that the questions did not require specific tailoring to the topics of ENGR 107. However, in considering mathematics self-efficacy as it relates to retention in engineering, two revisions were made to the MSES. The everyday math tasks subscale was not included in the survey, because a student's perception of their ability to perform everyday math tasks was assumed to have little effect on their decision to stay within a college major. The two other scales had direct applicability to the intentions of the study. The second revision was made to the courses subscale of the MSES, in which 8 of the original 15 courses were not included. Considering mathematics self efficacy with regard to engineering, the courses not included, while involving math, were not as clear as to the way in which math was associated with them and were classes that students were not likely to take as part of the engineering curriculum. Classes not included were physiology, business administration, philosophy, computer science, accounting, economics, zoology, and biochemistry. These efforts were made to ensure that the data is relevant and accurately reflects the intentions of the study.

The MSES was administered at the beginning and end of the course. Although the surveys contained instructions, intentional effort was made to reinforce to the students that their responses should be depictions of *confidence* and that they were not to try and solve any of the problems. Students were reassured that all information would remain confidential and that the surveys were not associated with their performance in the class, nor would they be evaluated until the course was over. The researcher did not look at the surveys until after the course was complete and final grades had been submitted.

C. Qualitative Interviews

The development of the pre-course protocol was based on Usher's (2009) qualitative investigation of the sources of mathematics self-efficacy in middle school students (Barker, 2010). Although her protocol questions were intended for middle school students, the questions that were chosen for our protocol addressed the construct of self-efficacy in ways that would still have relevance at the college level. Some of the questions included in the protocol were also used in a study by Hutchison-Green et al. (2008) on the engineering efficacy of first-year college students. The protocol followed a semi-structured, open ended format by engaging students in questions that were fashioned to yield responses about the students' mathematics self efficacy and the sources that influenced them; however, they were not designed to limit or lead the students' answers in any way. The pre interview questions focused on students' math backgrounds, experiences with math and people, and expectations for ENGR 107. The post interviews were designed to elicit responses regarding experiences in the class (i.e. mechanisms/sources) that influenced students' efficacy. Both protocols contained multiple questions that addressed student's beliefs about their current (at the time of the interview) mathematical ability and feelings toward upcoming classes. These questions and their purpose will be discussed in the upcoming data analysis section.

My experiences as the instructor, including consistent interactions and observations with students in class, in my office hours, and during lab sessions, allowed me to experience the day to day occurrences in ENGR 107. At two separate times during the course I was given the opportunity to quietly observe students as they worked together on a homework assignment. By prescribing to the methods outlined by Glesne (1999) for participant observation, I employed the use of both descriptive and analytical note taking. Through cross checking my observation notes with notes from experiences in the classroom and lab settings, I identified emergent patterns that would not have been apparent without exposure to the course settings (Glesne, 1999). Prior to teaching ENGR 107, I had received extended exposure to current research on mathematics self-efficacy, gaining an understanding of the four sources of efficacy and the ways in which they have impacted students. Consequently, the emergent patterns I identified were used to develop additional questions for the post interview protocol serving the dual purpose of providing feedback for course improvement and displaying impacts of sources on students' efficacy. A list of sample questions for both protocols is outlined below in Table 2.

Table 2-Sample Interview Questions

Pre Interview Protocol	Post Interview Protocol
Efficacy Sources and Influence Sample Questions	
1. Tell me about a class that you felt confident in your ability to perform the tasks you were given. 2. What have your teachers told you about how you are in math? Did that change how you feel about your ability in math? 3. How do you think ENGR 107 will affect how you feel about math?	1. What experiences have affected your confidence in math? How and why? 2. Tell me about some positive and negative aspects of the class.
"Current State of Efficacy" Sample Questions	
1. If you were asked to rate your ability in math on a scale of 1 (lowest) to 10 (highest), where would you be? Why? 2. How do you feel about your upcoming college math courses?	1. If you were asked to rate your ability in math on a scale of 1 to 10, where would you be? Why? 2. What math class are you planning on taking during the spring semester? Tell me about your feelings towards this upcoming class.
Emergent Topic Sample Questions	
(not applicable)	1. Would you advise future students for this class to take notes and why? 2. What are your feelings toward the textbook for the class? Were there things about it you specifically liked or disliked? 3. Did you enjoy the lab activities? What was your favorite lab and why?

Each interview took place in a small, quiet room and lasted approximately 20-25 minutes for the pre interviews and 12-15 minutes for the post interviews. It was decided as a safe means of practice for me, the instructor, to perform the initial interviews because I had no established relationship with the students and the questions focused heavily on students' background experiences with math. The post interviews were conducted by another graduate student who was familiar with the topic of efficacy and for whom I described the types of responses each question was intending to elicit. Had I conducted the post interviews, students' responses would easily have been biased due to my presence as an authority figure that they inevitably would associate with their grades for the course. Although the interviews were described as voluntary, my authoritative position may have influenced students to feel obligated to participate (Anderson and Herr, 1998); in which case students were reassured that the interviews were in no way associated with their performance in the class and that their responses would remain confidential. Students were encouraged to give descriptive responses and that there were no wrong answers. All interviews were audio recorded and later transcribed for data analysis.

D. DATA ANALYSIS

The survey scores were analyzed using the procedures outlined by Betz and Hackett in the manual for using the MSES (1993). For the class population as a whole, the scores for the math problems section and math courses section were analyzed separately. A paired sample t-test was performed for both sections, where the before and after scores were treated as two separate populations. Mean values, standard deviations, and significance levels were obtained for both sets of data.

Since this study is focused on the effects of ENGR 107 on each student, a more individualistic means of understanding is also required. Reliance on individual before and after aggregate quantitative scores was not a dependable means of analysis because the survey measurement was done using a Likert scale. For the purpose of comparing individual student scores, a Likert scale is not an objective measurement tool because the incremental change between 4 and 5 may not equal the incremental change between 7 and 8 in the eyes of a particular student. Therefore, what constitutes a "change" will most likely differ from student to student, meaning, for example, that a change of 5 points may be significant for one student whereas for a different student it is not. Therefore, we will conform to the same principle used by Hackett and Betz (1989) and base our microanalysis on the parameters obtained from the results of the population t-tests. It must be noted that although a similar principle was used to conduct the microanalysis, our chosen procedure was inherently different than that performed by Hackett and Betz (1989).

Based on the results of the paired t-test, individual student analysis of the math questions and math courses section were performed separately by comparing student mean responses to the population mean responses and standard deviations. Only after performing the t-tests did we have enough information to determine the necessary amount of change to be considered significant for the microanalysis. This data is presented in the results section following the population quantitative analysis. In order to present the data in a manner that is logical, simplistic, and complimentary to the qualitative method of categorization, students were categorized based on whether they experienced a significant increase, no significant change, or a significant decrease in their pre and post survey scores. This data will be used in conjunction with the data discerned from the qualitative procedure described next.

Qualitative data analysis occurred in two stages. For the first stage, the interview transcripts were coded following the *pattern coding* guidelines described by Miles and Huberman (1994). *First-level coding* involved funneling of the transcripts into broad sections of workable data. An initial round of pattern coding was performed on each first level code to identify prominent themes in student responses and to become familiar with the data. The second round of pattern coding was performed through the theoretical lens of self-efficacy. The intention of the interview analysis was to gain a perspective on students' mathematics self-efficacy sources; therefore the emergent efficacy themes were identified and coded within the first three efficacy sources under examination.

The coding procedure required extensive exposure to the interview data, through which I developed a confident understanding of the tone and intent behind students' responses. During both stages of qualitative analysis, this served as an additional source in determining whether data was coded in agreement with the intent behind each student's response. This process required the use of self-reflective measures of validity, what Miles and Huberman (1994) describe as a way of thinking in which the researcher constantly challenges their own understanding with findings from multiple sources in order to elaborate on similarities or differences in their interpretations. This definition refers to such things as constantly cross-checking between relevant statements within a transcript, readdressing codes as they apply to multiple sources, and taking into consideration interpretations that reflect researcher bias.

Following the coding process, the second stage of qualitative analysis was to categorize students' *current* state of efficacy at the time of each interview to determine, qualitatively, if a change occurred between the times of each interview. Although quantitative methods have been the typical means for addressing confirmatory questions, our intent was to provide further perspective on each student's change in efficacy by determining if a qualitative indication of change was made. During this stage of analysis, special attention was paid to two types of responses: statements of current efficacy prompted by the “current state of efficacy” interview questions and any such statement made as part of a response to any other question. A special note must be made regarding the post interviews: only “unbiased” questions were deemed acceptable; in other words, questions that were not associated with class experiences. Students’ self-efficacy in the class may not accurately represent their “unbiased”, general mathematics self-efficacy; thus, only statements depicting general mathematics efficacy and questions addressing general mathematics efficacy were accepted to satisfy the conditions of an unbiased response. Although any statement regarding current efficacy was sought after, likely due to the nature of the interview questions, in every case students’ responses remained limited to current efficacy in terms of feelings toward math ability (“I am good at math”) and feelings toward college math course performance (“I feel I will be successful in my future math courses”). These responses were analogous to the topics addressed on the MSES survey, which further justifies our decision to revise the survey to include only the specific components associated with this study. Each single student response was categorized as “high efficacy,” “medium efficacy,” and “low efficacy,” and tabulated similar to Table 3. Interpretation was limited to three different efficacy levels because, as Lent and Hackett (1987) indicate, further increases in specificity would likely lead to corresponding decreases in external validity. In other words, classification into more specific levels relies more heavily on interpretation, and higher degrees of interpretation would increase the difficulty of future researchers to obtain similar results and thus verify the findings from this study. Furthermore, for the purpose of this study, only relative change was of interest, not the levels between which it occurred.

Table 3-Types of Current Efficacy Responses

	High Efficacy	Medium Efficacy	Low Efficacy
Math Ability	"I am good at math"	"I am ok at math"	"I am not that good at math"
Math Courses Performance	"I feel I will do well in future math classes"	"I am unsure, but I think I will do alright in future math classes"	"I am nervous for how I will do in future math classes"

The final stage of qualitative analysis was dependant on triangulation of quantitative and qualitative efficacy change results. In order to best validate this procedure, Mathison (1988) suggests "not only must the researcher report his or her data collection procedures but also the three levels of information [convergent, inconsistent, contradictory] from which explanations about social phenomena are constructed", thus the "plausibility of explanations are [made] public and open to discussion" (p. 16-17). In this light, convergent, inconsistent, and contradictory findings will be explained in order to clearly depict how any conclusions made were associated with trends identified in the results. Based on the change that was identified in each method (surveys and interviews), students were grouped into categories defined by their specific combination of efficacy change. Each category represents a set of students who experienced the class in a similar way. For example, one such category could include students who demonstrated an increase in efficacy on the surveys, but exhibited no change in efficacy in the interviews. The three alternatives for each method (increase, no change, decrease) made for a possible nine combinations of student categories. Following this procedure allowed us to maximize the potential of mixed methods research. Stronger inferences were made between identical survey and interview results, and comparisons of inconsistent or contradictory survey and interview results allowed for the construction of meanings that would not have been possible using solely a quantitative or qualitative methodology (Teddlie and Tashakkori, 2009).

Following categorization, the sources identified by students in the coding process were analyzed within each group to identify whether certain mechanisms/sources were more or less prevalent than others; thereby shedding light on how efficacy sources in ENGR 107 potentially led student's efficacy to respond in the way that was indicated. In order to facilitate meaningful group comparisons, only groups with a common efficacy response were compared (illustrated in Figure 2). In other words, by experiencing a quantitative and qualitative increase, group one would be compared only to groups that experienced either a quantitative increase or a qualitative increase.

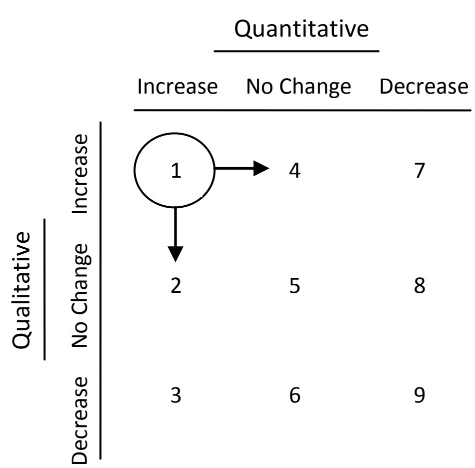

Figure 2- Method of Group Comparison

V. Results

A. Quantitative Results

After performing a paired sample t-test on the two sets of data, the results showed an increase in math problem solving efficacy from a mean of 7.3 with a standard deviation of 1.0 to a mean of 8.0 with a standard deviation of .66 and was significant at the 0.01 confidence level. No significant change was observed on the math courses efficacy subscale, which increased from a mean of 7.0 with a standard deviation of .90 to a mean of 7.1 with standard deviation of .89. Both scales were evaluated for internal reliability and found to have reasonable internal consistency (pre and post alpha coefficients of 0.85 to 0.9 for math problem solving and .58 to .77 for math courses). The low internal consistency reliability for math courses efficacy is potentially concerning, although possibly indicative that students had not yet developed a general sense of efficacy toward college math courses because they were new to the college environment and the level of difficulty associated with such courses. If the t-test had shown a significant increase in math courses efficacy the implications of the lower alpha values would be a cause for concern; however because no change was identified the risk of such a conclusion is minimal. These results are potentially significant when accounting for Pajares's and Miller's (1995) finding that math courses efficacy is stronger than math problem solving efficacy at predicting students' choice of math-related majors. Based on their findings, the lack of change in math courses efficacy indicates a lesser influence on retention in engineering. However, the participants in their study were representative of over 30 different majors, whereas the participants in this study have initially chosen a math-related major. The lack of change in math courses efficacy might therefore have different effects on *maintaining* students' choice of a math related major.

The lack of increase in math courses self efficacy is not unexpected for a number of reasons. Despite showing no increase in efficacy, the alpha coefficient value did increase by the end of the course, potentially indicating that students had become more accustomed to college math courses and developed a better sense of general math course efficacy (although that efficacy did not increase). It is also very likely that student responses on the pre survey demonstrated varying degrees of overconfidence for certain courses. In light of a similar association made by Hutchison-Green et al. (2008), since mathematics self-efficacy influences students' choice of a science related major (Betz and Hackett, 1983; Hackett and Betz, 1989), the fact that ENGR 107 students had chosen to pursue engineering would lend itself to the idea that they began the class with high levels of mathematics self-efficacy. While this information is still applicable to the study of students' efficacy, it dilutes the effects of the class on students' efficacy, thereby rendering the survey less effective at identifying whether or not a change occurred. Finally, the small 27 student sample size also subjects the statistical analysis to considerably more error than is present in typical large samples to which a t-test is usually applied. Although there were enough students to warrant the use of such a method, it also serves to justify the use of alternative methods as a means of data checking. In their study on the efficacy of a group of 22 students, O'Brien et al. (2000) found no statistical difference when performing a t-test on students' pre and post scores. However, noting the small sample size as a potential cause for data misrepresentation, the researchers performed an additional, more specified analysis (not similar to ours), which yielded statistically significant results not observed by the t-test. Although the intent of this study required a microanalysis be performed, the discrepancies observed by O'Brien et al. (2000) support our decision to further investigate the results given by the t-test.

Classifications of whether an increase, decrease, or no change in efficacy was observed were based on the high variability in population standard deviations. We believe this to be a justifiable method of approach since an efficacy change of .7 (from 7.3 to 8.0) on the t-test for the mathematics problem solving efficacy subscale was identified as significant at the .01 confidence level. In 3 of the 4 populations the standard deviations were far greater than a change of .7 (whereas in the fourth case the standard deviation was .66, nearly equal to .7). For the math courses efficacy subscale, the population change from mean value 7.0 to 7.1 was not statistically significant; therefore the pre and post population scores were nearly identical. The standard deviation for each population was considerable (.89 and .9), and as a result it was determined that a pre to post change of one standard deviation or greater would represent a change in efficacy. The standard deviation was determined by pooling the values from the two populations (.895). A similar procedure was followed for the math problem solving efficacy subscale, however with minor differences. As the population change from mean value 7.3 to 8.0 was significant at the 0.00 confidence level, it was expected that a majority of the students would not only display an increase in efficacy, but also a heightened amount of change compared to that of the math courses efficacy subscale. For that reason, students were classified by a change of one standard deviation *or* two standard deviations. The pooled standard deviation in this case was .83. The results of this analysis are presented in Table 4 below.

Table 4-Quantitative Microanalysis Results

Survey Subscale	Number of Students		
	Increase	No Change	Decrease
Math Problem Solving Efficacy	14	12	1
Math Courses Efficacy	4	18	5

It is not surprising that the results from the microanalysis reported two thirds of the class as displaying no change in efficacy; as this was the result of the sample t-test. Furthermore, this helps to explain why the t-test gave such a report. There were almost an identical number of students that experienced a quantitative increase as those that experienced a quantitative decrease (4 increased and 5 decreased). These groups counterbalanced each other, essentially causing the t-test to depict solely the results of the middle group, which experienced no significant change. These findings provide further justification for our decision to use additional means of analysis due to our small sample size.

B. Mixed Methods Results

The quantitative results were then triangulated with qualitative findings of efficacy change gathered from students' responses regarding their current state of efficacy at the period in time when each interview took place. To facilitate an accurate representation of student responses, all qualitative measures to identify a change in efficacy and sources of efficacy were performed prior to any quantitative measures in order to avoid any bias that could have been introduced by first observing the quantitative trends and then interpreting student interviews. Internal consistency for student responses of perceived efficacy toward future math course performance was without error. In other words, during each interview, students' responses to multiple questions, each addressing math courses efficacy in a different way, and any unprovoked statement students' made about their efficacy toward future math classes all fell within the same efficacy level category. Internal consistency for students' perceived efficacy toward math ability was less reliable for approximately one third of the class.

In these cases, students gave responses depicting different levels of efficacy (primarily either "high" and "medium" or "low" and "medium") depending on the variation of the question addressing this construct. Special attention was therefore given to the degree of impact of each statement to determine which was more representative of the student's efficacy beliefs. In the case that no such distinction could be made, "medium" efficacy served as a default; as statements involving noticeably high or low efficacy were not prevalent. An example of the qualification process for statements regarding students' current state of efficacy is provided in the following excerpts from student 26. Excerpt 1:

I: "Do you think this class has helped prepare you for other math classes in college?"

P: "For Calculus."

I: "Okay and how do you think it's helped you?"

P: "Just refined topics…"

In this instance the question was connected with the class and the student's answer was therefore influenced by efficacy sources specific to the class. In other words, identifying an efficacy source is not the same as a statement of efficacy belief. This response does not qualify as an unbiased statement of efficacy toward future math classes.

Excerpt 2:

I: "Would you recommend ENGR 107 and why?"

P: "…Good class to take in order to gain confidence to get prepared for calculus."

Although the question referenced the class, the student's answer specifically stated he was prepared for calculus, not simply a description of a source that is associated with preparation for calculus. Therefore this qualifies as an unbiased efficacy statement.

Excerpt 3:

I: "Tell me about your feelings toward this class (calculus)."

P: "I feel like I will do better than I would have if I hadn't taken this class."

The question does not address the class, leaving the student's response completely subject to their own discretion and thereby serving as an entirely unbiased representation of current efficacy.

Following analysis, mastery sources were found to be vastly more prominent than any other source for the capabilities measured by each subscale. However, Bandura (1997) suggests that in order for data to have predictive and useful value, self-efficacy regarding a specific math capability should be assessed via questions that address only the specific math capability in question. Similarly, the sources that influence efficacy must be identified with respect to the specific mathematical ability that was measured by each subscale. Therefore, the results will be presented to identify sources specific to each subscale (math courses efficacy and math problem solving efficacy) utilized in this study. However, due the small quantity of vicarious comparisons and social persuasions, these sources were not found to have explanatory power in the formation of student groups. Therefore, following each subscale discussion of prominent positive and negative mastery sources, general efficacy sources that were commonly mentioned but were not common among students in a particular group or math subscale will be briefly discussed.

1. Math Courses Efficacy

Analysis of the quantitative and qualitative data yielded the following group classifications based on the different combinations of efficacy change determined by the math courses subscale and student responses of efficacy toward future math courses.

Table 5-Math Courses Efficacy Groups

Quantitative	Qualitative	Group	Students
Increase	Increase	1	2
	No Change	2	2
	Decrease	3	-
No Change	Increase	4	5
	No Change	5	11
	Decrease	6	2
Decrease	Increase	7	-
	No Change	8	4
	Decrease	9	1

An analysis of each group from Table 4 was performed to identify dominant sources, trends, and discrepancies common among the group members that would account for why ENGR 107 impacted their efficacy in the ways apparent. Groupings that involved a higher number of students made convergence on sources that were common to each student in the group very difficult. In such cases the most prevalent sources within the group were identified as the most likely contributors to the efficacy changes identified by the group. Unless specifically noted, it was determined that if an efficacy source was common among 80 percent or more of the students in a group, it was considered significant.

Recognizing smaller, more subtle efficacy changes was difficult with the chosen qualitative method and although the results depict an accurate representation of the interviews, incremental changes may have occurred for the students in the qualitative "no change" category that could not be identified using the interviews alone. In comparison with other groups, this means that students who did not fall under the qualitative "no change" categories described a larger magnitude of change. This limitation can also serve as a ceiling effect with regard to students that began and ended the class with a high level of efficacy but who may have actually seen an increase in efficacy as a result of the class. This is likely apparent in the following comment by student 25,

> *"I'm pretty confident right now, probably about a nine [out of ten] because I mean like I said I'm doing well in this class and this is the best I've done pretty much in a math class so far so and I am looking forward to next semester."*

This particular student began ENGR 107 with high math courses efficacy. In this case, although his efficacy may have increased, it did not have the opportunity to increase as much because it was initially high to begin with. However, in similar situations, although the student may have described the class as having had a positive influence, it is still possible that the student's efficacy was not influenced if they already possessed a high degree of efficacy prior to the class.

Group 1- Quantitative "Increase", Qualitative "Increase"

The two students in group 1 identified a variety of common mastery sources. With regard to math courses efficacy, the most prominent were learning the material by way of outside resources and the instructor's teaching strategy, feelings of preparedness for calculus via the calculus material covered in ENGR 107, test grades, and filling of knowledge gaps left by previous math classes. It is suspected that by experiencing an atmosphere in which the students were able to positively experience the advantage of outside resources (tutors, internet, etc.), and in which the teaching strategy complimented the student's learning strategy, both students developed heightened efficacious feelings towards future math courses. As student 16 stated,

> *"I learned a lot about the tutoring centers here on campus. During the first few weeks of this class, I had to use those quite a bit. But I know I could use those for calculus too. So that's fine."*

His successful use of on-campus tutor services and knowing that they were available to help him in future math classes increased his efficacy for performance in those future classes.

Prior to ENGR 107 both students identified a preference toward application problems. Since such problems were a foundation for this class it is possible that the engineering application problems enhanced their efficacy towards engineering, and therefore the math classes associated with it, although student 12 did not reference them as an efficacy source following ENGR 107. Despite whether the engineering application played significant role, both students did identify exposure to calculus problems as a positive efficacy source because it prepared them for their upcoming course.

The most interesting commonality between the two students was their dual recognition that they were in need of some "catching up" as a result of their most recent negative high school class exposure. The feelings expressed by both students can be seen in a comment made by student 12, *"I'm probably lower because I took stats like the past couple of years. So, I haven't taken like an algebra-based course in awhile. So, I'll probably have to do some review to catch up…"*

By identifying that they needed to catch up to an implied previously attained level of knowledge and, at the end of the class, describing that they had filled gaps in their knowledge base, both students appeared to have achieved a goal that they had set for themselves. These results expand the domain of Schunk's (1985) study of sixth graders, where it was found that self set goals led to the highest promotion of self efficacy. By attaining their goal in their first college math course, the student's efficacy was heightened for future math courses in college.

Group 2- Quantitative "Increase", Qualitative "No Change"

The only commonality between the two students in this group, who both began the course with high math courses efficacy, was the efficacious impact of the placement test toward the students' feelings of preparedness for calculus. The placement test served as a milestone to these students because they had to work towards it over time and pass it to prove to themselves their readiness for advancement to calculus. As student 19 states,

"I didn't just place into it (calculus), I had to go through to high school, didn't place into it, then I had to come here (WSU), didn't place into [it] in the beginning, and then I had to take another class (ENGR 107) to place into it. So I just [have] had that much more background to go into the class."

Although this increase in was not mirrored qualitatively, it helps to explain why the students exhibited an increase in their quantitative efficacy score.

An interesting contradiction arose between specific efficacy sources described by the students. Student 25 identified positive sources that included his class grade, test grades, and instances of learning that occurred from the teaching strategy, homework, and labs; whereas student 19 identified instances of the exact same sources as negative efficacy sources. This contradiction shows the possibility that small setbacks do not severely impact students with high starting math courses efficacy in light of the experience as a whole. The sources mentioned by student 25 likely contributed to the increased efficacy displayed in his quantitative results. A different interaction between ENGR 107 and efficacy is apparent in the case of student 19. This student described the class as a review; therefore it is possible that seeing familiar material in the college setting helped maintain his starting efficacy level despite specific instances of misunderstanding and poor performance. It could also be, as Schunk (1991) suggests, that by having high efficacy, the student felt he shouldn't have had to persist as long on problems or assignments, thereby negatively influencing his expended effort in the course.

It is especially interesting that out of the entire class the only students to identify a lack of recent exposure to relevant material as a negative mastery source were three of the four students that belonged to groups 1 and 2. This self-acknowledging need for improvement may likely have contributed to the significant increase identified in the students' quantitative results. In other words, because they had not recently experienced courses they felt were relevant to the upcoming ENGR 107 class, their exposure to the course significantly boosted their efficacy towards college math courses. The discrepancy in efficacy change observed between groups 1 and 2 is most likely the combined result of group 2 possessing higher efficacy at the onset of the class and group 1's feelings that they had accomplished a goal. This discrepancy brings to light the notion that, following ENGR 107, a lack of change in efficacy should not be interpreted as the class having had no benefit towards student retention. With regard to efficacy, the intention behind the course was to sidestep the negative efficacy experiences students often have in first year of the engineering math curriculum. In that respect, students whose efficacy increased or was maintained throughout ENGR 107 benefited from their first semester experience by reaffirming their efficacy during a critical educational transition period in which it is highly vulnerable to influence (Gore, 2006). This can be seen in the following comment made by student 19 (group 2) who did not demonstrate any change in efficacy:

> *"…it was a good beginning class for the transition into college I feel like and it kind of helped me learn study habits for college and just moved me into the college math programs."*

Group 4- Quantitative "No Change", Qualitative "Increase"

Despite their survey results, distinctions between the pre and post interviews of the five students in group 4 illustrated a genuine change in efficacy toward math courses. The prevalent mastery sources were the placement test, feelings of preparedness for calculus via the calculus material covered in ENGR 107, and filling of knowledge gaps. Two other common sources, which included learning homework concepts through application of classroom examples and textbook examples, were questionable as to their connection with math courses efficacy. The placement test was identified as an efficacy source by four of the five members in the group. For two of these members it was viewed in the same way as it was by group 2, as a milestone signifying preparation for calculus. The second set of students viewed the placement test only as a source of confidence and motivation, as student 23 illustrates,

I: "Would you say that Engineering 107 has helped your confidence in mathematics?"

P: "Yes. Because I understand more about math I guess. I did a lot better on the ALEKS [placement] exam the second time. So that helped with confidence, stuff like that."

Despite differences in the ways each student interpreted the results of the placement exam, their impact can have equal influence on student efficacy, as is evident in the inconsistent findings among students in group 4.

The calculus material and the filling of knowledge gaps were sources common between groups 1 and 4. They are therefore perceived to have had similar effects on group 4; although the quantitative increase evidenced in group 1 would indicate a lower impact on group 4. It is also evident that group 4 did not recognize that they needed to "catch up" whereas group 1 did. Therefore, by achieving an intended goal, the students of group 1 were able to benefit more by filling gaps in their knowledge. With regard to class examples, this source was common among a multitude of groups throughout both subscales. Although other sources can be more clearly suggested regarding their association with the abilities measured by each subscale, it is unclear as to the affiliation between class examples and specifically math courses efficacy. It may be that these sources simply contributed to a general sense of math efficacy; in which case it carried over into student's math courses efficacy and math problem solving efficacy. It does however provide positive feedback for the active learning, example rich structure of ENGR 107, despite being unclear as to how it directly affects student efficacy.

Group 5- Quantitative "No Change", Qualitative "No Change"

Among the eleven students in group 5, the prevalent positive mastery sources accounted for at least 73 percent of the group, and one common negative mastery source accounted for 64 percent. The positive sources included learning of general class material, learning in lab sessions and by application of class and textbook examples to homework, and feeling prepared for calculus. Interestingly enough, the negative mastery source was misunderstandings that occurred as a result of confusion during lab sessions. The contradiction between the lab session as both a positive and negative source may likely have contributed to why the students' efficacy remained unchanged by the course. For example, early in the interview student 10 states,

> *"Like the labs, like they kind of implement engineering ideas into the labs so it kind of needs like the math that we use in the class and also like engineering ideas."*

However, later in the interview when asked about the lab sessions, student 10 responded,

> *"I mean they went over the stuff we went over in class that week so I guess it kind of reinforced it, but it didn't relate enough to really help me."*

Although the student understood that the material was relating to engineering, he admitted that the context was too displaced to help him learn and benefit from the experience.

Although group 5 described various specific sources that led to their feeling prepared for calculus (calculus exposure, pre calculus exposure, and the placement test), none of them was considered significant enough to stand out among the others. Comparisons made between groups 4 and 5 illustrate insightful results. Although both groups identified preparation for calculus to be an influential efficacy source, it is likely that they were perceived as more influential for group 4, since they exhibited the same quantitative change but an increase in qualitative efficacy over group 5. This is contrary to group 2 who perceived preparation for calculus (via the placement test) in a similar fashion to group 5, however their quantitative increase demonstrates that the potential effects of the source were likely more pronounced for group 2.

Group 6- Quantitative "No Change", Qualitative "Decrease"

Although they exhibited no statistical change, the two students in group 6 displayed noticeable declines in efficacy towards math courses after participating in ENGR 107. The students identified an array of common positive mastery sources, including understanding concepts, learning in lab sessions, and application of class examples to homework. Two interesting findings surfaced as a result: the first was that results indicated a vast variety of misunderstandings that occurred between the two students; wherein one student identified confusion during lab sessions as a negative source and the other identified confusion of homework and class examples as a negative source. The second finding was the only misunderstanding both students had in common, which were instances of misunderstanding concepts in general. This situation is similar to that of group 5 wherein the negative and positive lab experiences acted to counterbalance each other; but in the case of group 6 the negative experiences likely overpowered the positive experiences, as is shown in the following comments made by student 6 (group 6):

I: "Do you feel that you were successful in the Engineering 107 course?"

P: "Somewhat, yeah."

I: "Somewhat."

P: "Got a good understanding of most things, but once it got into the hard stuff or the more advanced calculus or pre calculus stuff, started to struggle a little bit."

Later in the interview, when asked about his feelings toward his upcoming calculus class, the student responded,

"Little scary for it, but once I get a full understanding by the end of the semester about these last parts of calculus or derivatives and integrals or whatever, I'll feel a little bit stronger about it, but…"

Although he felt he understood "most things" in ENGR 107, his misunderstandings clearly had an overpowering effect on his math courses efficacy.

The discrepancy between groups 4, 5 and 6 is apparent in the prevalence and impact of negative mastery sources. Group 4 did not identify any prominent negative efficacy sources, which likely contributed to their qualitative increase in efficacy. Group 5 identified the single, lesser negative experience of misunderstandings in the lab session (lesser, meaning it only affected a specific portion of understanding in the class); which was also simultaneously offset by a synonymous positive experience (learning in the lab session), thereby contributing to an overall lack of change in qualitative efficacy. Group 6 identified a more powerful negative experience, because misunderstanding concepts not only affects every facet of learning in the class, but also can make difficult the understanding of future topics that are required to build on those misconceptions. Therefore, by not understanding certain topics in ENGR 107, group 6's qualitative decrease in math course efficacy may demonstrate that they did not feel their knowledge was adequate to build on in subsequent math courses. This comparison demonstrates that even in the presence of positive mastery experiences, based on the degree of impact, negative mastery experiences can dominate the influence of a course on students' math courses efficacy. It is important to note that although some students in the other two groups described similar amounts of negative mastery sources to those in group 6, their effects were not present in their expressions of current efficacy, and therefore they affected those students to a lesser degree. Such sources were not strongly represented in other groups, thus supporting that each group of students did in fact satisfy the conditions of their category.

Group 8- Quantitative "Decrease", Qualitative "No Change"

The efficacy sources commonly expressed by group 8 were learning via the application of class and textbook examples to homework. The previous discussion regarding the lack of relevance of this source to specifically math courses efficacy would suggest a less obvious commonality among the group that explains their similar experience in ENGR 107. Examination of identified efficacy sources in the students' preliminary interviews indicated one potential explanation to be initial overconfidence in the course. Three of the four students stated that they had "always been successful in math"; and although the other student did not, he (student 7) did make the following comment about his experience:

> *I: "And what experiences have affected your confidence with math, with this class or in the past?"*
>
> *P: "I think just the shock of coming in thinking I was ready, but I really wasn't. I realized like halfway through or a little bit after that, that my math background wasn't strong enough yet."*

The student recognized that relative to his current efficacy, he began the class with a heightened level of efficacy. A high starting efficacy that was potentially due to overconfidence could explain why group 8's quantitative scores experienced a decrease; in which case the qualitative scores would be a more accurate representation of efficacy change. In contrast to group 2 (which displayed the same qualitative response, but increased quantitatively) this explanation makes sense in light of group 2's predisposed feelings of need for improvement, which likely contributed to the increase in efficacy they displayed. Likewise, group 8's high initial efficacy likely contributed to the decrease in efficacy they displayed. The mechanisms/sources that explain this decrease remain uncertain since no efficacy source from ENGR 107 could be identified to confidently explain the specific experiences of group 8.

Group 9- Quantitative "Decrease", Qualitative "Decrease"

Group 9 only consisted of a single student, which makes convergence on the most prevalent sources impossible. Therefore a more in depth, case study approach is required. Upon entering the class, when asked about her math ability, student 24 said,

> *"I'm really good at algebra and stuff, [but] when we got into the real calculus studies part of it I wasn't as strong…I'm good at it (math) and I just need to work at it, I think, to make sure I'm strong in all areas."*

She indicated that calculus studies were a previous source of negative mastery for her and that she needed to improve her skills in that domain. In her interview following the class, she constantly returned to the same powerful negative mastery source, to which she repeatedly conveyed the following feelings:

"I don't feel like I've been like, 'oh yeah, I totally did things a lot better.' Like it's mostly just like we go over things and then I like don't understand them. And then we actually like study like outside of class and figure stuff out."

By feeling that she "didn't do things a lot better", the student interpreted ENGR 107 as a second failure in her attempt to develop her calculus skills. The student did point out that she was able to "figure stuff out" from sources *outside of class*; sources which she described in her interview to include study buddies, class examples and notes, and examples from the textbook. However, later in her interview she states,

"Just because some of the things that we went over, I felt like I like didn't really understand why we were doing them. But I just did them and like followed procedure to figure out the problems."

Accordingly, her experience in ENGR 107 was limited to an understanding of *how* to use procedures, not *why* to use them. This awareness and perceiving her performance in ENGR 107 as a second failure attempt to learn calculus very likely contributed to her decrease in math course efficacy. This relationship is directly illustrated in the student's comment about her upcoming calculus class,

"But I don't think that I'm—like I passed the ALEKS [placement] exam, so I guess I am ready for [calculus] 171. But like, I don't know. I'm like nervous to go into it because I feel like [with] this class, I was just like—I didn't learn that much in it."

In comparison with group 6 (which showed the same qualitative decrease, but displayed no quantitative change), it seems evident that although both groups identified the same powerful negative mastery source (among others as well), the fact that the student in group 9 interpreted them as a second failure likely caused them to impact her efficacy more severely. With regard to group 8 however, because no efficacy sources were identified, it is difficult to understand what caused them to exhibit no qualitative change while group 9 showed a decrease. In the instance that group 8's results did represent a degree of overconfidence, it is likely that such overconfidence correlated with less expectation for math skill improvement. In effect, not seeing such skill improvement during ENGR 107 would therefore have a higher impact on the efficacy of the student in group 9, who outwardly described her intention to improve her skills for her future calculus class.

2. Math Problem Solving Efficacy

Student categories based on responses to the survey math problem solving efficacy subscale and interview responses addressing ability are presented in Table 5. It is evident that in certain cases the degree of change observed on the surveys did not substantiate a similar degree of change recognized in the interviews. This further supports the limitation that smaller increments of efficacy change were more difficult to detect by way of the interview method; however, comparatively, this signifies a larger magnitude of change described by students that did not fall under the qualitative "no change" categories.

Table 6-Math Problem Solving Groups

Quantitative	Qualitative	Group	Students
Increase	Increase	10	2
	No Change	11	10
	Decrease	12	2
No Change	Increase	13	2
	No Change	14	10
	Decrease	15	-
Decrease	Increase	16	-
	No Change	17	1
	Decrease	18	-

Group 10- Quantitative "Increase", Qualitative "Increase"

The students in group 10 identified a substantial amount of mastery sources, the majority of which were highly positive. These included the placement test, filling gaps in their knowledge base, learning material in general and specifically through labs, teacher office hours, and by applying classroom examples to homework. By performing well on the placement test the students likely proved to themselves that they had made significant improvements in ability since the start of ENGR 107. Student 18 describes this effect in response to a question addressing the impact of the placement test,

> *"Positive because I felt more confident in my math abilities after that. And then there was a catch 22 where when I felt a little too confident and I ended up getting some problems wrong that I shouldn't have."*

The student's overconfidence indicates that his efficacy noticeably increased as a result of his performance on the placement test.

Similar to groups from the previous section, by identifying that they had filled knowledge gaps, group 10 felt that they had developed abilities they didn't have prior to ENGR 107. By learning material in a vast variety of class-associated settings as listed above, the group had multiple successes to reinforce a heightened sense of ability. As a result, both students generally felt prepared for their upcoming calculus class based on their various successes in ENGR 107, as portrayed by student 18,

> *I: "And then, what experiences do you feel you've had the have helped you prepare for Math 171 (calculus)?*
>
> *P: "Basically everything in Engineering 107."*
>
> *I: "Anything specifically, maybe?*
>
> *P: "Trig, definitely, when we went over trig. And the derivative and integral stuff that we're doing right now."*

Although both students identified instances of misunderstanding due to the teaching strategy, they both mentioned that they were able to overcome their misunderstandings either during class or during teacher office hours. As student 18 states,

> *"And whenever I had questions, I'd go and ask him. And then he'd explain them as best as he could and that definitely helped."*

Both students referred to the fact that they were able to always get their questions answered. Having multiple, small successes in the class by way of consistently overcoming small misunderstandings appeared to significantly improve their belief in their ability to solve math problems.

The final commonality within group 10 was their observation of the fast paced nature of the course. Although they spoke of it as a negative aspect of the class, they did not identify it as negatively impacting their efficacy. When asked to explain the reasoning behind his math confidence, student 17 remarks,

> "*Because I believe he taught the class pretty well even though he went kind of fast on the material, but I still got it.*"

This comment portrays the sentiments of both student's, and an insight into why their efficacy was highly impacted. Vygotsky (1978) describes the *zone of proximal development* as the learning environment that is most conducive to effective student learning. This zone operates between environments that do not challenge the student and lead to less engagement in the class; and environments that are too difficult and in which the student feels they cannot succeed, thereby also leading to lesser engagement. In ENGR 107, group 10 experienced a fast paced class that provided a specific level of challenge, allowing the group to overcome such challenges and experience success, resulting in a heightened efficacy for math ability.

Group 11- Quantitative "Increase", Qualitative "No Change"

Despite describing no significant increase, the ten students in group 11 converged highly on a number of largely positive mastery sources. These sources included learning the material, understanding homework through application of class examples, and feeling prepared for calculus through exposure to calculus material. Confusion during the lab session was the only notable negative mastery source; however its significance is questionable, as it was recognized by only 60% of the group's members. By learning the material presented in ENGR 107, students very likely made a positive correlation to an increase in their ability, as student 12 indicates,

> *I: "If you were asked to rate your ability in math on a scale of one to ten, where would you be and why?"*
>
> *P: "Hmm, ability, in the long term, not very high. But right now, as far as like the stuff I've learned, I'd probably say like an eight."*

This student's belief in his current ability was directly affected by what he learned in ENGR 107. Specific instances of how students learned, including application of examples from class and the textbook to their homework, were prominent mastery sources as well. By having such available resources, students felt they were able to better understand the homework problems, which contributed to an overall increase in problem solving efficacy. Student 16 describes this phenomenon below,

> *I: "Would you advise future students of this class to take notes? Why?"*
>
> *P: "Definitely. Just like I said, you can use them when you are looking back at the homework because they're the same type of problems just different numbers. So you can follow them step-by-step and the more you do it, the more you understand it."*

Finally, the calculus portion of ENGR 107 proved very effective with group 11, as the majority of students who described feeling prepared for calculus referenced calculus material as their primary reasoning. It makes sense that such exposure would lend students to a heightened sense of problem solving efficacy because other equal level classes present solely pre calculus material. Student 4 explains his sentiments regarding this additional exposure,

> *I: "And do you think you'll be successful in this upcoming class (calculus), and why?"*

P: "I think so. Because I might be a little bit ahead because of the calculus we're going over now."

Based on their respective commonalities, understanding the material may have been more effective for group 10 because they noted that they had filled holes left by previous math courses with knowledge from this course; which was not a prevalent source in group 11. Although three of the students in group 11 experienced a two standard deviation increase in their quantitative score, analysis of efficacy sources showed no commonality between the three, aside from the sources previously identified, that explains the substantial increase. This speaks to the various levels of impact an efficacy source can have and its dependency on the individual in question.

Group 12- Quantitative "Increase", Qualitative "Decrease"

Group 12 was the only group among either subscale in which the quantitative and qualitative results contradicted each other. Furthermore, the quantitative increase that occurred for the two students in the group was an increase of over two standard deviations. Such a large contradiction can be explained by the common background experiences within the group. Prior to college, both students proclaimed that math had always been a subject they excelled in and easily understood. Following their experiences in ENGR 107, both students described misunderstanding general concepts and experiencing difficulty in applying them to homework problems. Student 19 explains his experience here,

I: "After taking the class, would you say your confidence in math has increased, decreased, or remain unchanged and why?"

P: "It's decreased a little bit because I was always confident in math in high school, so it was really easy for me and I came here [and] it wasn't as easy as I remember it being because I haven't taken math in two years so."

Both students experienced challenges in a subject they had been accustomed to excelling in; making it difficult for them to feel as though their abilities had improved. Despite this initial unfamiliarity with their math experience, group 12 did indicate common positive mastery sources that help to explain their quantitative increase. These specifically included feelings of preparation for calculus via all the material learned in ENGR 107 and also viewing the placement test as a milestone to enter calculus. These sources clearly correlate with an increase in efficacy; however their association with such a substantial increase is likely due to both students' exposure prior to the course. One student had not taken a math class in two years whereas the other had never been exposed to pre calculus material. It is likely that the students began the class with low efficacy in math ability specific to the course, experienced the previously mentioned mastery sources, substantially increased their efficacy, and partially masked their perceived improvement with a perceived decrease in general math problem solving efficacy based on the challenges they were not accustomed to experiencing.

Unlike groups 10 and 11, group 12 identified significant negative mastery experiences that help to explain why they perceived a decrease in math problem solving ability. Group 10's negative experiences could be used to generate more successes in math problem solving. Group 11 did not identify any substantial negative mastery sources as helping or hindering their successes in the class. In addition to their negative experiences, group 12's feelings were intensified by the collision between their successes in high school and the unexpected challenges they faced in ENGR 107.

Group 13- Quantitative “No Change”, Qualitative “Increase”

The mastery sources common among group 13 were strikingly similar to those identified by group 10, thus limiting the range of explanations behind the quantitative increase experienced by group 10. Such common sources included filling knowledge gaps, the placement test, and learning by way of lab sessions and application of class examples to homework. One additional source recognized by group 13 was test scores. The discrepancy between the two groups is most likely attributed to group 13’s lack of negative mastery sources. Between the group members, only one negative source was identified by one student. It would therefore seem that ENGR 107 did not provide a significant challenge for group 13. This is evident in the following statement by student 9,

I: “How would you rate your confidence (in math)?”

P: “Probably a nine.”

I: “Okay and why do you say that?”

P: “Yeah because everything makes sense right now, I feel I can do any problem.”

Although they felt their math ability had improved and described their experience efficaciously, the feeling was not reflected in their survey scores because they were not provided with a significant amount of obstacles; and accordingly the successes that resolve from overcoming those obstacles. They were able to maintain their efficacy, however chances for true improvement were not provided for group 13.

Group 14- Quantitative "No Change", Qualitative "No Change"

The students in group 14, having exhibited no change as a result of ENGR 107, converged on only one specific source within the class: application of classroom examples to homework problems. The other sources of mastery were with respect to the class in general, including feeling prepared for upcoming math classes (calculus or pre calculus) and for college math classes in general. Following the placement test, 24 out of 27 of the ENGR 107 students tested into calculus. The three students that did not test into calculus were among the students in group 14. It is interesting to note that despite their failure to test into calculus, not only did their efficacy remain constant, but also they felt better equipped to succeed in future math courses. Student 21 did not test into calculus, and states,

> *I: "Do you think this class has helped you prepare for other math classes in college?*
>
> *P: "I definitely think it has. It's my first math class because I'm a freshman, and so, like, it kind of gives me, like, a taste of what's going to come up next."*

The specific way in which ENGR 107 made students feel prepared for future math courses varied among the group, the most common being an introduction to future engineering courses (although this only accounted for 50% of the group).

The lack of specific sources helps to explain the effect of ENGR 107 on the students in group 14. Unlike group 11, learning the material was not a prominent source. This is not to say that learning did not occur, but students' lack of reference to it indicates that it was not viewed as a powerful contributor to their efficacy. Although neither group described a change in their efficacy, the difference between identifying learning as an efficacy source and not identifying learning as an efficacy source could likely explain the quantitative increase experienced by group 11. The distinction from group 13 is very similar. There were four sources identified by group 13 that allowed them to experience successes, to which they proclaimed themselves as having learned topics they were previously confused about. While 60% of the students in group 14 did speak of ENGR 107 as a review of material they had already learned, it was not deemed a significant amount. However, considering this fact and the lack of reference to learning the material, this helps to indicate why group 14 did not qualitatively increase as group 13 did. It can also be noted that lab confusion was also identified by 60% of group 14 as it was in group 11, but with the addition of misunderstanding concepts (identified by 60% of the group as well). These negative mastery sources may have also contributed to group 14's display of no efficacy change.

Group 17- Quantitative "Decrease", Qualitative "No Change"

Group 17 only consisted of one student, for which a case study approach similar to that which was performed for group 9 is required. Despite identifying a considerable number of positive mastery sources, the statements made by the student were highly supportive of his qualitative result. The student identified that he had gained a better understanding of pre calculus and calculus, but only to a minimal extent. As student 26 demonstrates,

I: "Do you feel you'll be successful in Math 171 (calculus)?

P: "Yes. Just because the focus is mainly more on calculus and I took a calc class last year so I already have a basic understanding of the topics."

I: "Okay. What specific experiences do you feel you've had that are going to help you prepare for the Math 171 class?"

P: "Just taking that class senior year, I guess, the AP class."

When later asked specifically about ENGR 107, the student did say that it was helpful for "refining" calculus topics; however it is clear that his feelings toward his math ability and preparation for calculus were controlled by his high school exposure. His perceptions of his high school experience also help to explain his quantitative score. During the initial interview, the student stated that math had always come easy to him before his calculus experience in his senior year of high school. ENGR 107's focus on primarily pre calculus topics may have caused him to develop an initially high level of math efficacy. Such overconfidence would explain why he showed a decrease in efficacy and group 14 did not, despite both of them having not referenced learning the material as an efficacy source. Although his efficacy appeared to decrease after the class, his statements reveal the seemingly minimal influence ENGR 107 had on his efficacy and how it was unchanged from beginning to end.

3. Non-Specific Efficacy Sources

The mastery sources identified in association with the abilities specific to the assessment of each subscale accounted for the majority of powerful mastery sources described during student interviews. Positive mastery sources that were commonly identified but not found to be specific to student groups in either subscale included the context of engineering application problems and review of the material; both of which were referenced by more than one third of the students. Whereas certain groups indicated filling of knowledge gaps, or learning concepts previously misunderstood in former math classes, to be an efficacy source; review of the material refers to feelings that students had refreshed their knowledge of topics they felt they already understood. These experiences are illustrated below by the comments of student 14 (group 4) and student 10 (group 5):

Student 14: *"…there are things that I didn't really get in the earlier math classes through high school, and this helped me to fully understand and be more confident in doing it."*

Student 10: *"I mean it was mostly a review for me because I took the class in high school so it just like reinforced my knowledge of the concepts."*

Students who felt they had built up their math skills were seemingly more likely to experience greater efficacy change toward math courses than students who felt they had simply "fine-tuned" skills that they had already acquired.

Although these sources cannot help to explain the difference in student experiences in ENGR 107, their significant contribution to students' efficacy is still of relevance to the effects of ENGR 107. This is highly evident in this statement made by student 2,

I: "Would you say that Engineering 107 has helped your confidence in mathematics? Why or why not?"

P: "Definitely because since it takes math and applies it to those real world concepts, I feel that like out in the real world, like I can kind of take those numbers and everything I need and know where to plug it into my equation…"

It can safely be assumed that such effects would not have been found in a standard mathematics class.

Vicarious comparisons and social persuasions were mentioned to a minimal extent following ENGR 107, which likely accounts for why they were not found to be associated with student groupings in either subscale. It is also likely that, as Bandura (1997) states, the influence of mastery experiences can be more easily generalized, whereas the effects of vicarious comparisons and social persuasions are more specific to the individual. Prior to ENGR 107, the only common vicarious comparisons among multiple students were both positive and negative comparisons to peers regarding a general understanding of math material; which also constituted speed of understanding in some cases. Following ENGR 107, understanding and speed of understanding remained the common vicarious comparisons with the addition of comparisons of class level. These included positive comparisons of ability to students in lower math courses and negative comparisons of ability to students already in calculus or higher math courses. As student 10 illustrates,

> *I: "And how would you say you compare with the rest of the students at WSU in your math abilities?"*
>
> *P: "I don't know. I started on pre calc and I know like a lot of engineering students are in to calc one so maybe not as high as- I'm probably like the middle of the pack."*

Although small in quantity, these comparisons show clear relevance to retention in engineering and must be understood.

Social persuasions were the least recognized source with regard to ENGR 107. During initial interviews, students were asked specific questions about friends, family and teachers as potential sources of social persuasion. Results for all three persons generally fell in line with Schunk's (1983) findings that ability feedback was more influential than effort feedback or ability-effort feedback. In this case, telling students "you're good at math" (ability feedback) positively influenced their efficacy, whereas telling them "You can be good at math if you work hard" (effort feedback) or "you work hard at math" (ability-effort feedback) did not have influence. Aside from the interview questions that specifically addressed potential social persuasions, the only unprompted instances of social persuasion that were mentioned were students getting asked questions by their peers. After ENGR 107, peer questioning was the only social persuasion identified by students.

VI. Limitations of Study

The intention behind this study was to group students in a way that was meaningful and accurately depicted the effects of the most influential efficacy sources. While this is not to say that students within each group didn't experience other sources, by converging on the most prevalent efficacy sources in different conditions, we isolated the most powerful sources and their potential contribution to variations in the students' experience. However, specific decisions were made regarding what constituted as "significant" during both quantitative and qualitative measures of change, as well as during measures of source convergence. These choices and the reasoning behind them have been previously discussed. It is likely that changing these parameters would lead to variations in student groupings and possibly different converging efficacy sources. However, the fact that the mastery sources identified through convergence of student groups were representative of almost all of the most mentioned mastery sources helps validate the procedures and precautions taken during analysis. Furthermore, group analysis allowed us to identify subtle, less mentioned mastery sources that would not have been recognized as significant otherwise. Based on students' responses to both measures of understanding efficacy, every effort was made that these sources and their varying levels of influence have been accurately depicted.

Future studies should consider the structure of ENGR 107 as a source of potential variance in students' efficacy experiences. A larger class size might possibly alter the respective influence of each of the four sources of self-efficacy. The results suggest positive student efficacy experiences from the active learning, example rich structure of the course. These findings could be substantiated by comparison with a traditional lecture-based classroom format to determine if an active learning atmosphere is of important benefit to students' efficacy. Lastly, the engineering application problems were not found to have explanatory power towards the efficacy experiences of any group. Although the chosen subscales of mathematics self-efficacy showed no direct influence, understanding the engineering context of math problems was a highly recognized mastery source in comparison with other mastery sources mentioned by the students as a whole. Similar studies in different contexts can further our understanding of whether the mechanisms/sources identified in this study are domain or context specific.

VII. IMPLICATIONS FOR EDUCATORS

The findings illustrate how different students interpret efficacy sources in different ways, as well as what considerations might be made for future implementations of the course to fit the needs of characteristically different student populations. Comparison of these sources within each group of students provided considerable insight into the conditions that were most conducive to learning. The most notable efficacy increases were found among students without recent, pre-calculus level math exposure and students who were challenged consistently throughout ENGR 107. With respect to the former, identifying that they were “behind” motivated students to set goals for themselves that, when achieved, left them with a heightened efficacy with which to begin their next class. Students must be encouraged to set learning goals for themselves so that they may have something to work towards; after which the successful feeling of achieving such goals can lead to increases in efficacy. To the latter, providing an environment that challenged students, but allowed them to overcome each challenge gave them the opportunity for more successes, and thus more chances for increases in efficacy. Students who were not provided with as many obstacles experienced less pronounced increases in efficacy or simply maintained their efficacy throughout the course. Although no change in efficacy is still viewed positively in light of the purposes behind this study, increases in efficacy should be the ultimate goal behind motivating retention.

Special care must be taken for students who enter the course with an initial efficacy that has been damaged by recent similar negative mastery experiences. Not only was it found that negative mastery sources can dominate over larger quantities of positive mastery sources, such negative effects can be compounded in students who are more efficaciously vulnerable and are experiencing similar negative performances for the second time. Similar effects were also witnessed for students who had previously excelled in math and were not accustomed to the challenges they faced in the college setting. Instructors must communicate to students that the difficulty level from high school to college math courses has risen dramatically, and that increased effort is required to sustain similar levels of success that students experienced in high school. Students must be made aware of the vast resources available to them in the college setting (peer tutors, teacher office hours, etc.), and that these resources are always available.

As this study demonstrated, knowing that help is available, whether it is used or not, can likely contribute to greater student efficacy.

VIII. Conclusion

This study determined the effects of an experimental engineering mathematics course on students' mathematics self-efficacy. This construct was chosen based on the established positive correlation between mathematics self-efficacy and students' choice of science-related major. From this study we determined that:

1. Students indicated a significant increase in math problem solving efficacy, but no increase in math courses efficacy.
2. Individually, students displayed consistent, inconsistent, and contradictory experiences of efficacy change in their responses to the surveys and interviews. Analysis of these responses illustrate that students' efficacy was largely either increased or maintained in ENGR 107.
3. Mastery experiences were the most powerful efficacy source in ENGR 107.
4. The most prevalent mastery experiences aggregated from the collection of group responses included: students' feeling prepared for calculus after having been exposed to introductory calculus material, learning that occurred through application of class examples to homework problems, correctly learning material that was misunderstood in previous math classes, and successful performance on the math placement test.

These results support the NSF initiative toward eliminating the mathematics bottleneck in engineering curriculums. Although the findings of this study cannot be generalized due to the specific nature of ENGR 107, they can be used to better understand the workings of mathematics self-efficacy in engineering contexts and to provide insight for the development of similar courses across the country.

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Appendix A: 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:

No Confidence at all	**Very little Confidence**	**Some Confidence**	**Much Confidence**	**Complete Confidence**
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

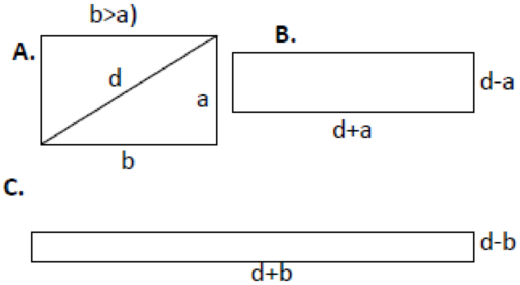
No Confidence at all | **Very little Confidence** | **Some Confidence** | **Much Confidence** | **Complete Confidence**

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.)

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
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.

APPENDIX B: INTERVIEW PROTOCOL

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?
- Tell me about your study habits in ENGR 107
    a. Did you feel you took notes on a regular basis?
        -Did you use your notes when working on homework or studying?
        -Did you feel the notes you took were adequate for completing homework?
        -If you did not take many notes, why?
        -Would you advise future students for this class to take notes and why?
    b. What are your feelings toward the textbook for the class? Did you find it helpful? Were there things about it that you specifically liked or disliked?
    c. What do you consider are the qualities a good textbook must have?
    d. How much time did you usually spend:
        -Studying for a test?
        -On a homework assignment?
        -On a single homework problem?
        -On a single homework problem before you got frustrated and moved to the next problem?
        -Do you feel you spent too much time, not enough time, or an adequate amount of time on these activities and why?
    e. Did you enjoy the lab activities? Did they help you understand the concepts that were taught in class? What was your favorite lab and why?
- 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?
    b. Did your performance on the math placement test in any way impact your performance or motivation in the class for the remainder of the semester?
- What math class are you planning on taking during the spring 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?