BRIDGING SECONDARY MATHEMATICS TO POST-SECONDARY CALCULUS:

A SUMMER BRIDGE PROGRAM

A Dissertation

by

SANDRA BONORDEN NITE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2012

Major Subject: Curriculum and Instruction

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Approved by:

Chair of Committee, Robert M. Capraro
Committee Members, G. Donald Allen
Mary M. Capraro
Jeffrey E. Froyd
Chair of Department, Yeping Li

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ABSTRACT

Bridging Secondary Mathematics to Post-Secondary Calculus:

A Summer Bridge Program. (August 2012)

Sandra Bonorden Nite, B.S.; M.S., Texas State University

Chair of Advisory Committee: Dr. Robert M. Capraro

The purpose of this study was to determine the effectiveness of early diagnosis and a summer program to strengthen precalculus skills before students enrolled in Engineering Calculus I. A meta-synthesis of interventions to increase success in college calculus was conducted, with a meta-analysis of studies that contained sufficient quantitative data to calculate Hedge's *g* effect sizes. Content validity for a mathematics placement exam was confirmed by an expert panel, and internal consistency of scores from 2008-2011 was verified using Cronbach's alpha. Effectiveness of a summer program to strengthen precalculus skills was measured by Hedge's *g* effect size. Results of content analysis of surveys given to tutors and students in the summer program were presented. ANOVA was used to compare mean GPA's of participants and nonparticipants of the summer program.

The meta-synthesis revealed that numerous strategies, some in precalculus and some in calculus, were successful for increasing success in college calculus. For the studies in the meta-analysis, the highest effect sizes were found in studies that used a

more comprehensive approach (e.g., collaborative groups and projects) rather than a single strategy (e.g., computer skills practice).

An expert panel determined that the exam was a good measure of requisite knowledge for calculus. One question was considered unnecessary for calculus and was not of a type addressed in precalculus and was eliminated from further analysis. Cronbach's alpha was consistently above .8 for each year's scores 2008-2011 and for each subset of scores by gender, ethnicity, and selected majors for 2008-2011. The 122 students who participated in the summer program increased the average score by 6.45 points (total of 33), with 81% of the students raising their scores above the cut score to take Engineering Calculus I.

Results of ANOVA to compare mean GPA's for students in the summer program and students who did not participate, both with placement exam scores in the range 16 to 21, inclusive, showed no significant difference. The summer program was successful in allowing some students the opportunity to strengthen their precalculus skills and take Engineering Calculus I a semester earlier than the control group.

Dedicated to

My parents, Arthur Henry and Robbie LeNell Bonorden,

Who instilled in me the love of learning at an early age and provided the opportunity for me to pursue a college degree

My husband, Michael,

Who has supported my quest for knowledge throughout almost 39 years of marriage

My precious daughter, Stephanie,

With whom I have the pleasure of sharing a graduation day

My father-in-law and mother-in-law, Marvin James and Lemma Lee Nite,

Who encouraged me in all my academic endeavors

My sisters, Sharon, Donna, and Janet,

Who cheered me on in my studies

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CHAPTER I

INTRODUCTION

Calculus is a necessary and required course of study for students in Science, Technology, Engineering, and Mathematics (STEM) majors, but many students are not prepared for the rigors of college mathematics, including calculus. Universities have been providing remedial education of some kind since the nineteenth century. When legislation mandated testing in the 1980s, about 30% of entering students lacked the necessary basic skills (Bettinger & Long, 2009; Breneman & Haarlow, 1998). The percentage of students requiring remediation has remained fairly constant since that time. However, the length of time spent in remediation increased (Parsad & Lewis, 2003).

There have been considerable costs related to remediation of reading, writing, and mathematics. Critics contended that taxpayers paid twice for instruction that should have been successfully completed in the elementary and secondary schools, taking funds that could be spent on other educational endeavors (Breneman & Haarlow, 1998; Parsad & Lewis, 2003). The cost of remediation was not limited to the estimated one billion dollars in federal and state budget money. Students themselves paid tuition costs for remediation and used financial aid resources that could have been allocated elsewhere. Delayed college graduation resulted in low wages and decreased labor productivity (Bettinger & Long, 2009; Breneman & Haarlow, 1998).

This dissertation follows the style of *Educational Researcher*.

The effect on the students enrolled in remediation has been mixed. Persistence and time to graduation, choice of major, and labor market returns were negatively impacted. However, compared to students with similar characteristics, remediation in English and mathematics reduced the likelihood of dropping out. For mathematics remediation, positive results on graduation probability increased as the student's ACT scores increased (Bettinger & Long, 2009).

The Department of Mathematics at Texas A&M University had the same concerns as other colleges and universities about student performance in mathematics. The success rates for Engineering Calculus I and Engineering Calculus II for the last four years at Texas A&M University have remained steady at a rate of close to 70%. Table 1 contains the success rates, pull and lag for Engineering Calculus I and II.

Table 1
Engineering Mathematics Success Rates

	Engineering Calculus I success rates		Engineering Calculus II success rates
Fall 2005	-	Spring 2006	60%
Spring 2006	58%	Fall 2006	58%
Fall 2006	66%	Spring 2007	66%
Spring 2007	62%	Fall 2007	54%
Fall 2007	66%	Spring 2008	61%
Spring 2008	60%	Fall 2008	71%
Fall 2008	70%	Spring 2009	-

Students entering Texas A&M University as entering freshmen in STEM majors were required to take a Mathematics Placement Exam (MPE) to determine whether they should take Engineering Calculus I or a preparatory precalculus course. According to available student data, many students do poorly on the MPE even though they had several advanced mathematics courses in high school, including AP Calculus. An intervention program was planned and implemented to increase the number of students who were successful in Engineering Calculus I and thus prepared for success in Engineering Calculus II. A grant was awarded from the National Science Foundation to design and implement an online summer intervention program to remediate specific areas of need. Results from the MPE and the course letter grades in fall of 2007 were used to design an intervention to improve precalculus knowledge requisite for college calculus. Therefore a process was developed to determine which students were likely to be unsuccessful in Engineering Calculus I so that they could be invited to participate in a six-week short course in precalculus topics customized for success in Engineering Calculus I and II. The intervention began in the summer of 2010, and results were used to refine the process for subsequent years.

Research Question

Can early diagnosis and an online summer program designed to strengthen precalculus skills improve student success in the first course in engineering calculus?

Predictors of Success in College and College Mathematics

High school performance has been closely linked to college success. Some of the predictors related to high school performance were GPA, class rank (rescaled on an 80-

point scale), SAT score, and ACT score (Baron & Norman, 1992). In fact, one additional factor has been shown to be important to entering college freshman success in science, engineering, and mathematics: academic self concept (House, 2000). Long term mathematics success for advanced students has also been linked to high school performance criteria. The two variables that emerged (adjusted $R^2 = 0.427$) for actuarial students were SAT score and high school percentile class rank (Smith & Schumacher, 2005). An additional variable that emerged from an examination of advanced mathematics students was a placement exam. The difficulty with this variable was that differed with each institution, and teacher variability had an effect on its predictive ability.

Student personality characteristics have also helped predict success in college courses. Results of a commitment questionnaire and self-appraisal of academic ability were both used successfully in predicting postsecondary academic achievement (Kluger & Koslowsky, 1988).

Predictors of Success in College Calculus

Considerable literature has delineated factors indicative of overall college success and success in college mathematics below the calculus level. The studies specific to success in college calculus were not as numerous, but were most relevant to the current study. Predictor variables for success in calculus included high school performance, SAT scores, ACT scores, high school calculus experience, placement exams, and personality factors.

SAT and ACT scores. A survey of 429 two-year colleges regarding placement practices for calculus revealed that the high school record was used as the primary factor in 78% of cases, along with math scores on SAT or ACT Almost half used a placement test, about half of those locally developed tests. (Jenkins, 1990). SAT and ACT scores were not only indicators for success in college mathematics in general, but composite scores and subscores were useful in predicting success in college calculus (Bridgeman, 1982; House, 2000; Messina, 2008).

High school experience. High school calculus experience also served as a solid predictor for college Calculus I. For many students AP calculus has become a stumbling block in the path to careers in science, technology, engineering and mathematics. In a 2010 study, 30 percent of students who took calculus in high school were placed into precalculus in college (Bressoud, 2010). Students who took a year of calculus in high school performed statistically significantly better in Calculus I than those with no calculus or only a brief introduction to calculus before college calculus. However, the gain was primarily in procedural fluency rather than conceptual knowledge (Ferrini-Mundy & Gaudard, 1992). Many students were shocked to find that they did poorly on the first college calculus exam (Bressoud, 2010). Although there was no statistically significant difference in performance in Calculus II, students who took high school calculus were more likely to continue on into the second semester of college calculus (Ferrini-Mundy & Gaudard, 1992).

College preparatory courses and placement exams. Preparatory courses taken in college have helped predict success in calculus. Students who entered calculus with lower grades in prerequisite courses were generally not successful (Yushau & Omar, 2007). In more recent years, many colleges were using locally developed placement exams along with high school performance and standardized test scores (Rueda & Sokolowsky, 2004; Stephens & Buchalter, 1987). At one university the correlation coefficient between calculus readiness test scores and final exam scores was calculated and found to be statistically significant, with $r = .42$ and $r = .55$ for the two forms of the readiness test (Stephens & Buchalter, 1987).

Placement exams were used not only to predict success, but to place students in courses where they were most likely to be successful. At one college, approximately 80% of students who took the recommended course or an easier one were successful over a period of five years (Rueda & Sokolowsky, 2004).

Self Regulation and Personality factors. Scores from various local and standardized tests as well as high school performance were not the only predictors of college calculus success. Important factors predicting success in calculus among freshmen engineering students included a student's ability to regulate his or her own learning in areas of classroom engagement and time on task (Mwavita, 2005). Certain personality variables such as persistence, responsibility, and patience contributed considerably to the prediction of success in college calculus classes (Shaughnessy, 1994).

College Calculus Interventions to Improve Success

A variety of strategies to increase success in calculus have been used. Some focused on the preparatory course, precalculus, and some focused on the calculus course itself.

Preparatory interventions. One college precalculus revision to increase mathematics learning included 1) smaller class size, 2) student collaboration in small groups, and 3) problem based learning. Three classrooms, each using one of these nontraditional approaches were compared to a traditional classroom. Students who needed to improve skills for success in calculus were randomly assigned to one of the four sections. Student test scores on four common exams revealed that students in the problem based learning class performed better than students in the other three classes, one that used a traditional approach, and two that used other nontraditional approaches (Olson, Knott, & Currie, 2009). A meta-analysis of small-group learning on STEM undergraduates resulted in the conclusion that different types of small-group learning increase student achievement (Springer, Stanne, & Donovan, 1999).

A discussion-based seminar format was deemed a successful strategy for teaching various levels of college mathematics. Students were required to read textbook materials, work relatively simple exercises, and submit a short reaction piece to the professor before attending class so that they were prepared for the discussion. More difficult homework exercises were completed after the class meeting. The professor believed the primary benefits of the seminar type instruction in his classes of size twenty or less were that students become more independent and more successful life-long learners of mathematics (King, 2001).

In a modeling-based college algebra course, students in the pilot course scored higher on common final exam questions than students in the traditional course. However, they did not perform as well in the precalculus course but did better in the business mathematics application course, both of which followed the college algebra course. A higher percentage of students who completed the modeling course also completed the subsequent course required for their majors (Ellington, 2005).

A workshop model based on Treisman's Emerging Scholars resulted in greater achievement in introductory mathematics courses, including college algebra and precalculus. Student workshop sections comprised a separate course in addition to lecture and recitation already in existence. Students worked on problem sets that consisted of review, practice for the current material, or previews of upcoming topics (Duncan & Dick, 2000). Similar results were reported in the McNeill Program at the University of Colorado at Boulder with at risk students in college mathematics courses involving workshops and collaborative learning (Mendez, 2006).

Calculus interventions. Interventions within or alongside the calculus course have proved successful in many instances. A placement exam was used to determine which students were at highest risk of failing calculus and would take a course that integrated precalculus review as needed throughout calculus, resulting in higher achievement (Maggelakis & Lutzer, 2007). The Emerging Scholars Program developed by the University of Texas at Austin added workshops to all calculus classes of about 25 students each integrating collaborative learning, in addition to the four lecture hours. The change was expensive but resulted in a 16.3% increase in student success in Calculus I. Other universities added workshops to several calculus courses, and found that it increased success rates (Duncan & Dick, 2000; Subramanian, Cates, & Gutarts, 2009).

Article 1

Research Question

What are characteristics of successful interventions for college precalculus and calculus over the last ten years?

Methods and Analysis

In the first article, the author provided results of a research synthesis of interventions at the college precalculus and calculus level. Searches were conducted in educational databases and Google Scholar. Of particular interest were those in the last ten to twelve years because of the rapid development in technology and the change in student characteristics as a result of the expansion of technology. For the eight studies that provided sufficient quantitative data, a meta-analysis was conducted to determine what effects could be expected from an intervention designed to increase precalculus skills before calculus enrollment. Results also informed the field about which types of interventions may have the greatest effects by comparison of Hedge's *g* effect sizes. The research synthesis helped determine what worked for today's students to improve their probability of success in engineering calculus so that their chances of success in the engineering major were increased.

Article 2

Research Question

How successful is the summer intervention in improving algebra and precalculus skills and increasing the passing rate on the Mathematics Placement Exam and entrance into Engineering Calculus I?

Participants

Participants were entering college freshmen who wished to take the first course in engineering calculus but had a raw score of 16-21 on the MPE. In order to register for Engineering Calculus I, students were required to score above 21 on a scale of 0 to 33. Participants who scored in the range of 16-21 were offered an opportunity to improve their knowledge of precalculus to a level that would allow them to take Engineering Calculus I. If they chose not to participate or failed to earn a score of 22 or better, they were required to enroll in precalculus when they enter Texas A&M University in the fall. Thus this prevents them from beginning the engineering course sequence.

Instruments

The Mathematics Placement Exam (MPE) was developed in 2006 and used beginning in the fall of 2007. The MPE contains 33 multiple choice questions over the topics of polynomials, functions, graphing, exponential functions, logarithmic functions, and trigonometric functions. Each of the 33 problems has 15 variants, resulting in 15^{33} different possible exams. The MPE was the instrument used to measure student progress in reaching the required score to be admitted to engineering calculus.

Personalized Precalculus Program (PPP)

The Personalized Precalculus Program was offered online in the summer for six weeks, at which time students could retake the MPE. However, students who did not participate in the PPP could retake the MPE after 30 days. The online chapter tests with algorithmic problems were used to measure progress in the four areas targeted by the precalculus intervention. Students were then assigned a personalized study program (PSP) and a tutor to guide them through the PPP.

Methods and Analysis

The instrument validity and score reliability were computed for the MPE, and content validity was examined. The reliability coefficient, α, for scores on the MPE, was computed for several years to show consistency in reliability for entering freshmen over a period of time. Cronbach's alpha for combined scores over four years was computed for groups by gender, ethnicity, and college of the student's major. An expert panel confirmed validity of the MPE for placing students in Precalulus or Engineering Calculus. The current precalculus intervention, into which students were placed according to MPE scores, was described, and how the development fit into the framework developed by the research synthesis.

Student skill levels before and after the summer precalculus intervention and their MPE scores before and after the intervention were analyzed with descriptive statistics. Cohen's *d* effect size and confidence interval were computed for MPE scores before and after the intervention. In addition, results from various surveys conducted with students and tutors were described, and content analysis of responses was conducted using qualitative methods.

Article 3

Research Question

How successful is the summer precalculus intervention for increasing the success rate in Engineering Calculus I for students with MPE scores between 16 and 22?

Participants

Participants were all of the freshmen in Engineering Calculus I in Fall 2011 and students who took Precalculus in Fall 2011 and Engineering Calculus I in Spring 2012. Students who made the cut score of 22 on the MPE could register for Engineering Calculus I, but some choose to take precalculus first. Students who did not make the cut score of 22 but scored above 16 were offered the opportunity to take the summer intervention in lieu of taking Precalculus in the fall. The cut scores were determined by finding the point at which 70% of students that performed above that score passed Engineering Calculus I with A, B, or C from fall 2008 through spring of 2010.

Methods and Analysis

The course grades in Engineering Calculus I for students who scored between 16 and 22 and took the summer PPP to enter calculus in Fall 2011 were compared with those who chose to take the Precalculus course in the fall and Engineering Calculus I in Spring 2012 as well as students who scored above 22 and took Engineering Calculus I in Fall 2011. A one-way ANOVA was used to compare group means.

CHAPTER II

INTERVENTIONS FOR SUCCESS IN ENGINEERING CALCULUS: A RESEARCH SYNTHESIS

The study of calculus is an important foundation for many majors and careers. However, students continue to struggle with calculus. In order to retain and try to increase the number of students in Science, Technology, Engineering, and Mathematics (STEM) majors, it falls upon the universities to provide interventions to accomplish the federal initiatives to encourage STEM majors and careers. The methodology for the meta-analysis (see p. 23) yielded results that included many studies that described interventions but included little, if any, quantitative data. Those students are described in the following paragraphs, and the meta-analysis follows. Interventions that have claimed success include the use of technology (Blanco, Estela, Ginovart, & Saà, 2009; Cerri & Barufi, 2003; De Mello, Lins, De Mello, & Gomes, 2002; Keynes & Olson, 2000; LaRose, 2010; Naido, 2007), adding engineering alongside precalculus or calculus (Hampikian, Gardner, Moll, Pyke, & Schrader, 2006; Loganathan, Greenberg, Holub, & Moore, 2004; Monte & Hein, 2003), integrating algebra and precalculus skills alongside calculus (Fulton, 2003), adding projects (Roedel, Evans, Doak, Kawski, & Green, 1996; Rodel, Evans, Doak, McCarter, Duerden, Green, & Garland, 1997), and using an integrated curriculum. A research synthesis was conducted in 2005 for integrated curricula in engineering, which included mathematics (Froyd & Ohland, 2005), but no research synthesis for calculus interventions was found.

Beginning in the 1950's a major reform movement in teaching calculus swept the United States and was spread throughout the world. Not everyone subscribed to the reform, but many educators did. The National Science Foundation (NSF) began providing grant funding toward the reform effort in 1987. A report on the impact of the NSF grants from 1988-1998 was published in 2001 (Ganter). The current research synthesis is a study of the interventions in precalculus and calculus from about 1998 through 2011. Although many of the studies cited above did not give sufficient data to compare effect sizes, they contributed to the literature on interventions for success in calculus. They are described in the next few paragraphs, and a meta-analysis of the studies with sufficient quantitative data follows.

Intervention Programs for Calculus Success

Interventions have evolved from mere skills remediation to more comprehensive programs involving several components. Most of the studies of interventions and course redesign since 1998 revolved around technology in some form. Often the goal was to help students visualize the graphs in calculus or to facilitate multiple representations of functions, derivatives, and integrals (Cretchley, Harman, Ellerton, & Fogarty, 1999; Dunn & Harman, 2000; GarcÍa, GarcÍa, Galiano, Prieto, Dominguez, & Cielos, 2005; Hausknecht & Kowalczyk, 2007; Pemberton, 2002; Varbanova, 2005). Some used computer algebra systems (CAS), while others used graphing calculators or computer software without CAS (Iglesias, Carbajo, & Rosa, 2008; Martin, 1994). Course revisions included an online precalculus course (Kennedy, Ellis, Oien, & Benoit, 2007) an online calculus course (Allen, 2001), realignment of calculus topics to match the concurrent engineering course (Barrow & Fulling, 1998; Whiteacre & Malavé, 1998), the addition of algebra skills testing throughout the course (Fulton, 2003), and adding projects to the course. Another focus for more recent interventions was the integration of other STEM content; sometimes language arts was included. Another strategy used was collaborative work among students with the goals to more closely emulate the environment they would face in the workforce and to help them learn to study mathematics more effectively (Duncan & Dick, 2000; Horwitz & Ebrahimpour, 2002; Roedel et al., 1996).

Loganathan et al. (1999) noted,

> Universities all over the country have embarked on various plans for better teaching of calculus. These may be grouped into three categories: (1) introduction of innovative instructional methods/aids, (2) reordering and in general minor additions and deletions of topics to serve a wider class of students, and (3) integration of mathematics, physics and chemistry with focus on a particular field such as engineering (p. 1).

Since 1999, technology has played a much larger role in calculus interventions. Thus, the studies that were collected were analyzed to classify the types of interventions used, keeping in mind the categories that Loganathan found and the new developments in technology. They were then grouped according to similarities that could be found among them, and the details were described within categories of similar studies.

Technology

Handheld technology. The only study found involving handheld technology in precalculus and calculus addressed the issue of students who used graphing technology extensively in courses prior to calculus. The students continued using the technology to solve problems in a traditional calculus course, although they could not use it on the exams. However, they were not troubled over the prohibition of the graphing technology on exams in the calculus course. The students who had used calculators to a large extent in the past solved routine calculus problems equally as well as students without the graphing technology background (Martin, 1994).

CAS systems. Several different software packages with computer algebra systems (CAS) were used successfully in calculus courses. Two systems were used in only one study. Java tools were used to create interactive tutorials for derivation in calculus. Applets were written to illustrate the geometric interpretation of derivative, with special emphasis on such topics and discontinuous functions, continuous non differentiable functions, relative extrema, Rolle's Theorem, the Mean Value Theorem, and increasing and decreasing intervals of functions. It was noted that interactive applets could be useful in online learning as well as being integrated into classroom lectures (Iglesias, Carbajo, & Rosa, 2008). Reports of the conversion on Mac-only software for use on other operating systems reported that the software enhancing teaching and learning in calculus, increasing student active participation and providing visualization of the mathematical concepts. Particular lesson included work with Hooke's Law for spring-mass systems, catenary hanging cables, Snell's Law of Refraction used in optimization, vector fields, and related rates (Hausknecht & Kowalczyk, 2007).

Derive software was used in teaching mathematics for engineers, and researchers asserted that involving students in activities in which they had to write command lines to solve problems required a deeper understanding of the subject matter and encouraged more active learning (GarcÍa, GarcÍa, Galiano, Prieto, Dominguez, & Cielos, 2005). In another study Derive specifically improved student understanding of the relationship between a graph and its first and second derivatives, approximation of Taylor and Maclaurin series, definite integrals, double integrals, functions of two variables, and first order ordinary differential equations. The authors concluded that computer algebra system technologies can help students improve thinking process and increase their understanding of mathematics and its role in their everyday lives (Varbanova, 2005).

The detailed description of a calculus and linear algebra program that integrated web-based Maple applications included the use of applications in the lectures and student work on similar ideas in succeeding lab tutorials over the course of twelve weeks. The first few tutorials involve considerable time for learning the software and syntax. Content in the calculus material included work with Taylor series, Gaussian elimination, vectors, and eigenvalues and eigenvectors. Conclusions from the work done with the program included suggestions that 1) The program must be used in the lecture as well as the computer lab for students to feel that it is an integral part of the course; and 2) Introduction of the computer algebra system needed to be aligned with lectures for students to realize the relevance. Student had some difficulty with the syntax of the program, especially if they were already weak in algebra. But for students who persisted through the program, the computer algebra system allowed them to illustrate and extend mathematical ideas that are typically difficult for students to grasp (Pemberton, 2002).

In a description of MATLAB programs used to enhance learning of concepts in calculus (Dunn & Harman, 2000), researchers cited as the reason for developing the modules that a prior study at the same university showed that students generally received technology-enhanced calculus well and that it helped to enliven the study of mathematics (Cretchley, Harman, Ellerton, & Fogarty, 1999). MATLAB lessons were designed to show students the algorithms used in calculus, including Newton's method, differentiation, and integration.

Online components or courses. The WebCalC Project implemented at Texas A&M University was designed for an online course. The course developers believed that an online course had to be easier for students to navigate and learn from than reading a textbook. To that end, complete solutions to examples and exercises, interactive quizzes and exams, and animation were among the components considered to be critical for success. Students performed as well as students in traditional classes in the course and subsequent courses, but they thought the online format was difficult (Allen, 2001). Several other technology-in-mathematics projects included the use of technology tools both in the classroom and outside the classroom, either in addition to classroom work or in an online class environment. Within or separate from the CAS systems discussed earlier, tools included ebooks, algorithmic problem sets, streaming videos, animations, and interactive applets.

A mastery learning online precalculus program was described, in which streaming videos and algorithmic problem sets were used. The streaming videos included 1) overview videos with corresponding documents, introducing mathematical concepts and definitions and explaining the objective of the unit, and 2) example problems worked out and explained. A graphing calculator was included in some of the problems, both in the example videos and the algorithmic problem sets that were used for assessment. Student tutors were available in the computer center. Students retook assessments until they reached 80% mastery. Results from surveys suggest that online tutoring and collaborative groups are needed for higher success (Kennedy, Ellis, Oien, & Benoit, 2007).

Course Revision

Calculus and engineering course alignment. Course alignment and integration was among the strategies used by a Foundation Coalition funded by the National Science Foundation to increase success in first year engineering courses (Cordes et al., 1997; Corleto, Kimball, Tipton, & MacLauchlan, 1996; Pendergrass et al., 1999). Calculus courses were restructured to align with physics, engineering, and chemistry courses that students took concurrently. At one university, the biggest change was to introduce vectors and multidimensional calculus concepts in the first semester rather than the third semester. Approximation techniques were emphasized more in response to needs in the beginning engineering courses. Topics that were traditionally studied early but were not critical to address early were moved toward the end of the calculus study. Topics sequenced later included more in-depth work with limits, the mean value theorem, trigonometric substitution, and partial fractions (Barrow & Fulling, 1998; Whiteacre & Malavé, 1998).

Mastery learning of algebra in calculus. In a precalculus "gateway testing" program, a set of knowledge and skills deemed critical by mathematics and engineering faculty was developed. In this case, the term "gateway" did not refer to a requirement to pass the tests before entering the course but before being assigned a final passing grade in the course. Students took tests of 20 problems each, and were required to master the material at the 90% level before moving on to the next topic or concept. Students required more tries to pass than expected; e.g., about 60% needed three tries, and many needed more. After two years of a pilot program, the program became a standard part of both semesters of freshman calculus to ensure that students have the basic skills needed for success in calculus (Fulton, 2003).

Projects with precalulus or calculus. Some programs used learning communities or integrated curriculum. However, in some cases, projects were added to the precalculus or calculus course to help students understanding how mathematics is used in STEM fields. Students in a calculus course for engineers worked together in groups to solve engineering-related problems. The program was designed to help students develop a deeper understanding of calculus concepts, use conceptual knowledge to model and solve engineering problems, and become more engaged and connected early in the engineering curriculum. The only significant problem encountered was a lack of time to take full advantage of the improved curriculum (Schneider, Kelley, & Baker, 2007).

A collaborative effort between the mathematics and engineering departments to integrate projects yielded favorable results with engineering majors. Students of other majors who were in the class were not as enthusiastic about the projects. Projects included work with polynomial function, fitting data with sine functions, average and instantaneous rates of change, piecewise functions, exponential functions and derivatives, and parametric curves. Although many students reacted favorably to the projects, increased understanding and motivation to learn calculus was not accomplished because often students could follow the examples given to successfully complete the projects without engaging in deeper thought or problem solving (Horwitz & Ebrahimpour, 2002).

Learning communities. Developing systemic mathematics knowledge, whether through groups of students in a course, teachers in schools, or units including various stakeholders requires an organizational structure to provide for a) shared understanding and responsibility, b) reflection on practice (studying and learning coursework), c) specified times to gather to share, and d) engagement of the learners (Sackney, Walker, & Mitchell, 2005). Students who were not ready to begin calculus in the first semester of college were grouped into integrated learning communities for math, English, chemistry, and engineering. They were required to complete a design project developed collaboratively by faculty and students. The project was designed for help students gain discipline and skills to become better problem solvers as they progress through their coursework. Although the program was successful, it was too time-intensive for instructors to be maintained in the same way as the pilot program (Jacquez, Auzenne, Burnham, & Green, 2005).

Supplemental workshops for students to work collaboratively to solve problems were initiated for college algebra, precalculus, and calculus. The program was designed to teach students to solve problems collaboratively and to learn how to study mathematics effectively. Participation in the program was voluntary, so higher grades for participants than non-participants could not be attributed solely to the program (Duncan & Dick, 2000).

An integrated program was offered to engineering students, for which groups of students would work together to complete projects. A webpage was designed to support the program, and videoconferencing was available (Roedel et al., 1996). Three engineering projects for the first semester were to design and construct a 1) catapult, 2) bungee-drop apparatus, and 3) trebuchet. Both faculty and students believed that the projects were very valuable (Roedel et al., 1997).

Cognitive Organizers for Success

A variety of other strategies to improve calculus success were found, each described in a single study. The common factor among the strategies was that they involved activities that would help develop cognitive skills in mathematics students. Each was determined to have a positive impact on student performance.

Students designed and played their own games in freshman mathematics courses for engineering majors. In designing the games, about 90% of the content was related to topics in the course. Some games focused on skills practice and some on development of conceptual understanding, e.g., geometric proofs played on the computer. Students were more motivated and interested in mathematics as a result of designing and playing the games (Gallegos & Flores, 2010).

Students in a class that focused on developing facility in moving between different representations of the derivative in calculus were more successful on post-test questions about the derivative (Goerdt, 2007). When a calculus course was taught with an outcome based approach, students were positive about having clear cut objectives and the opportunity to continue to practice to improve scores (Goulet, 2001).

Writing assignments in a calculus class were implemented to help students learn to express themselves in mathematical writing. Three writing assignments, with focus on conceptual knowledge rather than procedural knowledge, were designed. The first writing assignment was a one-page essay defining mathematics from the student's viewpoint. The second was to describe one particular family of functions, with a government agency as the audience. The third assignment was to write a "letter to Granny" about what the student had learned in calculus. Students gained a deeper understanding of calculus from writing about it to different audiences at different levels and synthesizing what they had learning for the entire semester or year (Green, 2002).

To eliminate misconceptions in mathematics, students were given incorrect statements and asked to provide counterexamples to disprove them. Most students believed the method was effective in helping them understand concepts better, eliminate mistakes in their work, develop critical thinking and that it made learning of mathematics more interesting (Gruenwald & Klymchuk, 2003).

Meta-Analysis Study

The result of the meta-synthesis provided information about interventions that were considered to be successful, although they did not provide sufficient quantitative data. Determination whether or not they were successful or to what extent was largely based on observations and surveys administered to faculty and students. On the other hand, studies that provide quantitative data contribute to the field in an additional manner because standardized effect sizes can be computed to help illustrate the extent to which various interventions are successful, and findings are generalizable through the meta-analysis.

By conducting a meta-analysis of interventions that provided sufficient quantitative data, the questions below can be answered:

1) Are interventions for calculus achievement successful, in general?
2) How successful are interventions for calculus success?
3) What are the characteristics of successful interventions?

Methodology

The search for interventions to improve algebra and precalculus skills was conducted through several means, including Google Scholar, several library databases, and cross-referencing articles found by other means. A search was conducted in Google Scholar for “engineering calculus,” a very general topic that would yield the most results. The keywords “precalculus,” “algebra,” and “calculus” were used to search the following educational databases: Educational Resources Information Center [(ERIC) via EBSCOhost], PsycINFO (Proquest), WebScience, and OmniFileFT Mega (Wilson). The studies of interest were those that used interventions designed to increase algebra and precalculus skills for calculus success, although they might include other strategies as well. Cross-referencing from relevant articles was performed to locate possible additional studies. Searches in the databases listed above for each author of relevant articles found, along with the keyword "calculus" were conducted in an effort to locate any other possibility of study publications by the same author. Because of advances in technology's effect on students and mathematics curriculum and instruction, and because of a synopsis of interventions funded by NSF previously (Ganter, 2001), the studies were narrowed to those published since 1998.

The various searches yielded an initial collection of 1,258 articles. However, many of the studies were not applicable, untraceable, or duplicates. The titles of the works were scanned, and potential studies were identified. Fifty-two articles were retrieved for further examination. Theoretical articles, articles employing qualitative methods, and quantitative studies without sufficient information to calculate an effect size were excluded, leaving eight articles for the meta-analysis.

Variables were recorded using a spreadsheet; coded variables were author, publication year, publication venue, intervention type, method of assignment, and whether the design included 1) random assignment, assignment by placement test, or students chose to participate, 2) pre- and post-tests, only post-test, course grades, or percentages passing, 3) type of treatment (mastery testing, projects, integrated curriculum, CAS software, learning communities, or cognitive organizers), and 4) length of treatment time. Unfortunately, most of the studies were not very explicit about the details of the design, making it difficult to determine how effective the design was in helping assert causality. The outcome measure for many studies was percent passing calculus; however, some studies used pre- and post-tests. In addition to percent passing the calculus class, some studies gave the mean grade point averages for the treatment and control groups. Only one effect size was used per study, so the percent passing was chosen for those that gave both the percent passing and the mean grade point average. When only percentage passing was given, Cohen's d was calculated from differences using the formula

$$d = 2\arcsin(P_{Exp}) - 2\arcsin(P_{Con}),$$

where P_{Exp} and P_{Con} are the percentage passing for the experimental and control groups, respectively (Dennis, Lennox, & Foss, 1997). Hedge's *g* was the chosen effect size, in order to correct for possible sample size bias (Cooper, 2010). The Q-statistic was calculated, and confidence intervals were computed. A funnel plot was constructed to more clearly depict the confidence intervals and each study's effect size in relation to the confidence interval. Because homogeneity over the whole group was not found (Q = 67.86; $p < .001$), the studies were grouped according to comprehensiveness of intervention, and the Q-statistic within and between groups was calculated (Lipsey & Wilson, 2001).

Results

Interventions that were included in studies with quantitative data useful for a meta-analysis were of two main types: 1) interventions in algebra and precalculus courses to improve skills necessary for calculus, and 2) interventions in the calculus courses.

Algebra and Precalculus Interventions

Two of the studies in the meta-analysis involved an intervention in the precalculus course. In both studies, an introductory engineering class was added. Experiments were used to illustrate engineering principles using algebraic and trigonometric equations (Hampikian, Gardner, Moll, Pyke, & Schrader, 2006; Monte & Hein, 2003). One of the programs also included online algebra practice and instruction in time management skills (Hampikian et al., 2006), but it had a small Hedge's *g* (0.17), possibly because the treatment group was very small (N = 17) compared to the control group (N = 104), but the other study showed very good results from the intervention, with a Hedge's *g* of 0.73. Results for the subsequent calculus class were not given in either case, although one study showed a higher retention rate in the experimental group (Monte & Hein, 2003).

Calculus Interventions

The interventions for the calculus class all involved technology in some way. For one study, the entire course was online, and the participants were students who had failed the calculus course previously. The intervention may have been successful had they been compared to other students who failed calculus previously and were retaking the traditional course. However, the comparison was made to a group that took the traditional course for the first time (Cerri & Barufi, 2003). One study replaced pencil-and-paper homework with online homework, resulting in a small positive effect size

(LaRose, 2010). Another study compared a group using computational aids in the form of computer software with a group that was traditional, resulting in a very small positive effect size as well (De Mello et al., 2002). The other four studies had more significant changes to the calculus course. In one case, a computer laboratory was used for interactive projects (Naido, 2007); in the second case, students worked in cooperative groups with projects and computer lab work (Keynes & Olson, 2000); in the third and fourth cases, an engineering class was added alongside the precalculus or calculus class, with experiments to illustrate engineering principles (Hampikian et al., 2006). The precalculus class with engineering had a small treatment group (N = 17) compared to the control group (N = 104), which could account for the fact that its effect size was considerably smaller than the other interventions that had extensive changes. Effects sizes for the three groups with more comprehensive changes (not including the one with a small treatment group) fell between 0.54 and 1.34, inclusive (see Table 2).

Table 2
Hedge's g Effect Sizes

Study	Hedges *g*	Control N	Treatment N	Total N
1	-0.30	750	146	896
2	0.12	80	80	160
3	0.17	104	17	121
4	0.78	68	28	96
5	0.54	100	100	200
6	0.16	158	208	366
7	0.73	52	59	111
8	1.34	34	34	68

The mean effect size was 0.44, and the weighted mean effect size was 0.17. Table 3 shows the Q-Statistics, and Figure 1 illustrated the results with a funnel plot. The large study is clearly an outlier because it is farther outside the funnel than any other point.

Table 3
Q-Statistics

Study	Hedge's *g*	Q-Statistic	Probability(Q)	Significant?
1	-0.30	26.833	< 0.001	Yes
2	0.12	0.103	0.748	No
3	0.17	< 0.001	0.996	No
4	0.78	7.018	0.008	Yes
5	0.54	6.524	0.011	Yes
6	0.16	0.010	0.920	No
7	0.73	8.257	0.004	Yes
8	1.34	19.119	< 0.001	Yes

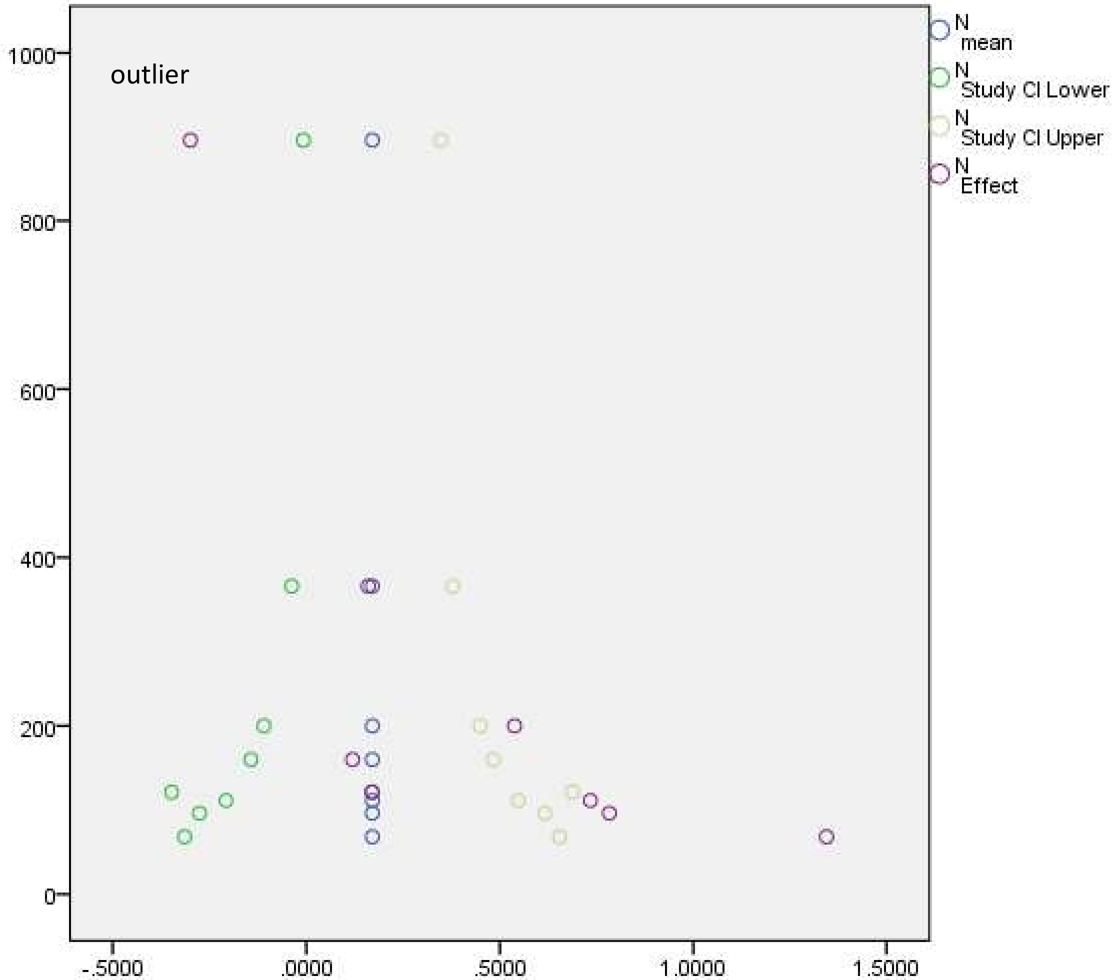

Figure 1.
Funnel plot.

The study with the largest number of subjects was the only study with a negative effect size. The experimental group consisted of students who had already failed calculus, and the control group of those who had not. Table 4 shows the results of eliminating that study.

Table 4
Q-Statistics with Outlier Eliminated

Study	Hedge's *g*	Q-Statistic	Probability(Q)	Significant?
2	0.12	0.103	0.748	No
3	0.17	< 0.001	0.996	No
4	0.78	7.018	0.008	Yes
5	0.54	6.524	0.0101	Yes
6	0.16	0.010	0.920	No
7	0.73	8.257	0.004	Yes
8	1.34	19.119	< 0.001	Yes

The mean effect size of the seven studies above is 0.55 and the weighted mean is 0.40. The *Q*-Statistic was 28.03, with a probability of 0.00047, showing that there is not homogeneity with the studies, and the effects came from two or more different distributions. Even if the *Q*-Statistic showed homogeneity, it would be advisable to examine for possible mediators or moderators.

For the remaining seven studies, two had minimal interventions, and five had more extensive course innovations. The spreadsheet results of the moderator investigation by dividing into two groups is given in Appendix A. *Q*-Between groups is 29.0987, and $p < .0001$, indicating that there is not homogeneity between groups; the means of the two groups were statistically significantly different. *Q*-Within is 11.2046, and $p = 0.0475$, indicating homogeneity within groups. It appears that the level of intervention was a moderator for these studies. The average effect size for the group with a minimal intervention program was approximately 0.14, while the average weighted effect size for the group of studies with more significant change was approximately 0.73.

One of the five studies with more extensive changes had a very small treatment group (N=17), which may have had an adverse affect on the results. Further, mediator analysis was conducted with that study eliminated (see Appendix B). The spreadsheet indicates no homogeneity of variance between or within groups. Q-Between is 32.7376, and $p < .0001$; Q-Within is 43.7843, and $p < .0001$. Without homogeneity within groups, it was unclear whether neither group or only one group fails the homogeneity test. Computation for homogeneity with each of the groups was conducted. The group with more extensive interventions was homogeneous, with Q = 7.0687, and $p = .0697$.

Discussion

Studies that included quantitative data were scarce; more studies are needed for various interventions, and success rates and amount of increase in mean course grades as well as pass rates should be reported. Often studies with quantitative data did not include standard deviations, so the freedom to choose the most appropriate effect size or to average effect sizes for the study was lost. Among the studies that provided sufficient quantitative data, those interventions that were more comprehensive or involved more than just changing to online rather than paper homework or just adding computer quizzes were more successful. Interventions that involved group work, technology in a meaningful way to teach or illustrate concepts, and projects are recommended for future studies to learn more about which components are most critical to success of the intervention or whether there must be a combination of components to better ensure success.

CHAPTER III

PREPARING FOR ENGINEERING CALCULUS I:

ANALYSIS OF A PLACEMENT EXAM AND SUMMER PROGRAM

In a research synthesis for interventions to increase success in precalculus and calculus in Chapter II, several interventions used tests either as placement into the intervention or to determine students' level of knowledge at the beginning of the program. In some cases, scores on a standardized test, such as ACT or COMPASS were used to place students (Hampikian, 2006; Keynes & Olson, 2000; Monte & Hein, 2003). In one case a regression model using high school GPA, math SAT, and whether or not the student took calculus in high school was used to place students in the program (Loganathan, Greenberg, Holub, & Moore, 1999). Gateway testing or formative assessment of skills at the beginning of the calculus course and/or the midpoint of the course was used in some programs, and these tests were locally written (Blanco, Estela, Ginovart, & Saà, 2009; Cretchley, Harman, Ellerton, & Fogarty, 2000; Fulton, 2003; Goulet, 2001; Kennedy, Ellis, Oien, & Benoit, 2007; LaRose, 2010). None of the studies reported reliability or validity of scores for any placement or gateway testing. In one case, some item analysis, such as facility index, discrimination index, and discrimination coefficient, was reported (Blanco et al., 2009).

It is important for researchers to report score reliabilities, estimation methods, and confidence intervals to help readers understand the meaning of the estimates and to provide a basis for meta-analytic thinking and comparison of studies (Capraro, 2004; Fan & Thompson, 2001). In addition, psychometric information is important for determining the quality of the evidence that would be used to affect practice. In fact, score reliabilities are effect sizes and should be reported with CI's just as they should be for other effect sizes. However, statistical significance for score reliabilities should not use the nil null hypothesis that score reliability is 0. Such a test will almost certainly result in rejecting the nil null. Instead, the nil null hypothesis should specify a number such as .50 or .80, which are more reasonable for reliability coefficients (Fan & Thompson). Not only should score reliability coefficients be reported for the data currently being analyzed, but should be given for prior studies involving the instrument. Reliability is not a characteristic of the instrument but of the scores. It cannot be assumed that prior or current score reliabilities will be representative of future scores unless the subjects and conditions are similar (Capraro & Capraro, 2002; Capraro & Capraro, 2009; Fan & Thompson, 2001; Henson, Capraro, & Capraro, 2001). In addition, score reliabilities should be reported for subgroups of interest, not for only the entire sample (Capraro & Capraro, 2009).

Methodology

Mathematics Placement Exam (MPE)

The Department of Mathematics had been using an exam to place students into either Precalculus or Engineering Calculus I. Initially, results were used for advisement, but beginning in Fall 2011, students with scores below the raw cut score of 22 out of 33 were blocked from registering for Engineering Calculus I. Cut scores were determined arbitrarily by virtue of the fact that past data showed that at least 70% of students scoring 22 or better were successful in Engineering Calculus I by earning a grade of A, B, or C.

MPE validity. Syllabi for all instructors currently teaching Precalculus and Engineering Calculus I were gathered to determine content and construct validity. An expert panel was selected, based on long institutional history, strong content knowledge, and extensive experience teaching Precalculus and Engineering Calculus I (see Table 5). One member had extensive experience teaching Precalculus, one had extensive experience teaching Engineering Calculus I, and two had experience teaching both courses.

Table 5
Expert Panel Experience Teaching Precalculus and Engineering Calculus I

Content Expert	Course	Number of Sections	Number of Semesters	Time Period	Other
1	Precalculus	19	10	2001 – 2011	SV
2	Engineering Calculus I	35	20	1995-2011	SV; WIR; CC
3	Precalculus	8	3	2006-208	WIR; CC
3	Engineering Calculus I	2	1	2010	WIR
4	Precalculus	1	1	2012	
4	Engineering Calculus I	1	1	2009	

Note: SV = Streaming Videos; WIR = Week in Review; CC = Course Coordination

For each of the 33 questions on the MPE, the expert panel was asked 1) whether the question related to content taught in Precalculus and 2) whether the material tested in the question was necessary in Engineering Calculus I. The panel was then asked whether there was additional content that was necessary for Engineering Calculus I that was not tested.

MPE reliability. Results from the MPE scores from 2008 through 2011 were analyzed collectively and by year. Table 6 shows the breakdown of students who took the exam 2008 through 2011, by gender and ethnicity. Table 7 shows the breakdown of students by college.

Table 6
Gender and Ethnicity of Students Who Took the MPE 2008-2011

Year	2008	2009	2010	2011	Total
Female	924	1080	1106	862	3972
Male	1885	1932	2281	1694	7791
Black	97	106	103	69	375
Hispanic	489	510	646	452	2026
American Indian	9	11	8	6	34
Two or more, not black or Hispanic	51	60	92	73	276
Native Hawaiian	5	8	7	2	22
Asian	156	215	218	177	766
International	48	45	62	23	178
Unknown	0	0	8	7	15
White	1954	2057	2243	1747	8001
TOTAL	2809	3012	3387	2556	11,763

Table 7
College of Study of Students Who Took the MPE 2008-2011

Year	2008	2009	2010	2011	Total
Agriculture	343	367	293	174	1178
Architecture	106	115	117	66	404
Business	170	115	96	7	388
Education	206	210	161	60	637
Engineering	1235	1319	1474	1055	5082
Exchange Program	0	2	5	0	7
General Education	90	79	109	83	361
Geosciences	0	66	479	621	1166
Liberal Arts	366	351	220	46	983
Science	249	328	384	423	1384
Veterinary	43	60	49	21	173

Design of Personalized Precalculus Program (PPP)

The Personalized Precalculus Program was designed as a mastery learning intervention to include several components that were considered important for student success. Figure 2 illustrates the PPP process: 1) pre-test, 2) students enrolled in online learning focused on their individual weaknesses identified in the pre-test, 3) tutoring and self-study personalized study program (PSP), 4) benchmark testing for each category, and 5) repeating the process until mastery was reached for each category.

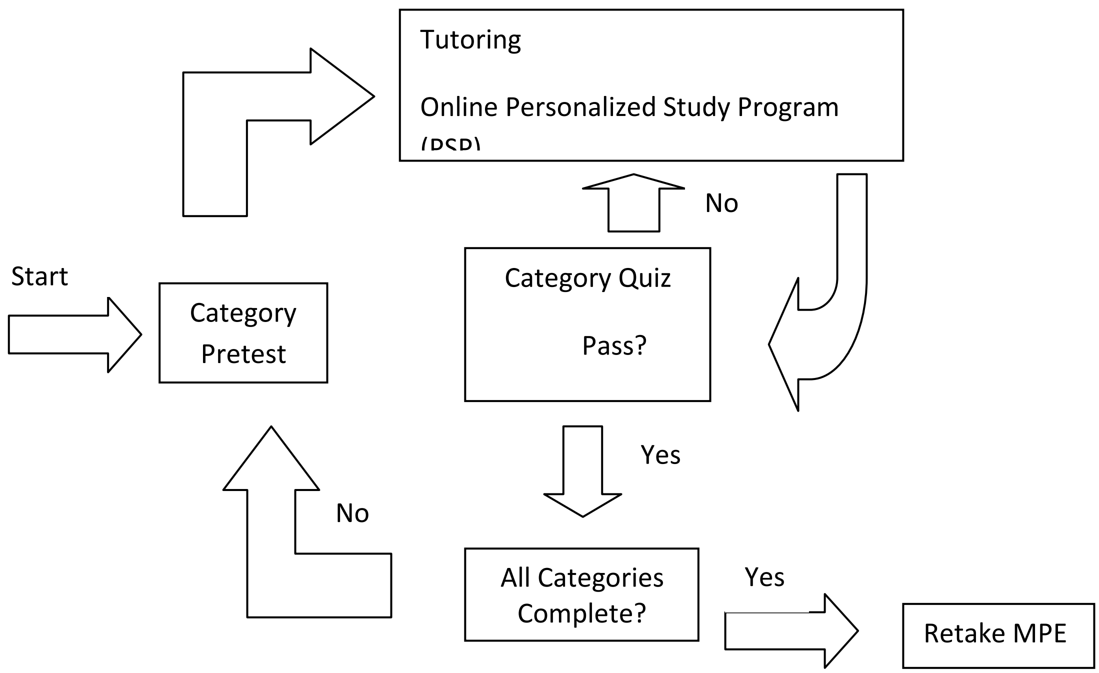

Figure 2.
Personalized Precalculus Program process.

Analysis of the MPE revealed that students tended to be underprepared in three major categories, which were then be disaggregated into several subcategories each (See Appendix A). Students scoring in the range 16-21, inclusive, on the MPE were offered the opportunity to participate in the PPP. If they were able to improve their MPE scores to 22 or above, they could enroll in Engineering Calculus I in the fall. Students could be given permission to retake the MPE 30 days after initial testing. In the fall term, students whose highest scores on the MPE were below 22 could enroll in Precalculus but not Engineering Calculus I. Students who chose to enroll in the summer program were assigned to a tutor and registered in the online homework and quiz system.

Personalized Study Program (PSP). In the PPP, students took an assessment in an online quiz system to determine which two or three of the four categories most needed to be remediated. The system provided a Personalized Study Program (PSP) visual by means of a histogram with green, yellow, and red bars to indicate areas students had mastered and areas where students still needed work. After completing algorithmic problem sets in each subcategory at 80% mastery, students could retake the category or chapter test again. If their score exceeds 80% across all remediated areas, then after 30 days they could take the MPE again.

Synchronous online tutoring. Each student was required to attend biweekly 90-minute tutoring sessions. Tutors set up two pairs of sessions per week for students to choose one to attend. The conferencing software allowed the tutors to load Power Point® slides or graphic files to use for teaching the students. Both were able to write on a whiteboard to explain problems, and tutors could divide students into groups or individual breakout rooms to solve problems on the whiteboard. The students could then be reconvened in the main room to go over the problems together. While students were working, the tutors could move through the rooms to answer questions or ask students questions to help them work through the problems.

Online resources. The online homework/quiz system included electronic resources in addition to the sets of algorithmic problems. Linked to each subcategory were textbook section(s), short instructional and example videos, and Power Point® slides in conjunction with the videos. Problems with answers were included in the electronic textbook that students could access.

PPP and MPE Scores

Ten tutors conducted 12 six-week PPP sessions, with a total of 204 students participating. During summer, 122 students in the program retook the MPE. Mean scores and SD's before and after PPP participation were calculated. Cohen's *d* was calculated with confidence intervals for the effect size.

PPP Surveys. After the completion of the online summer program, online surveys were administered to tutors and students. The tutor survey contained 16 items to rate on a 5-point Likert scale and seven free response questions, with a 240-character limit for each one (see Appendix B). All ten tutors completed the survey, with the average response time 20 minutes. The student survey contained 10 items to rate on a 5-point Likert scale five free response questions, with a 240-character limit for each one. Sixty-seven students out of the 122 students in the summer program (55%) completed the survey, with an average response time of nine minutes (see Appendix C). Content analysis of the responses was accomplished by first unitizing (i.e., breaking down into small units of meaningful information) the responses to open-ended questions from the tutors. Then the units were read and reviewed several times and finally divided into three main categories (cf. Lincoln & Guba, 1985; Erlandson, Harris, Skipper, Allen, 1993): 1) responses that applied to management of the program, 2) responses that applied to materials in the program, and 3) responses that referenced one of the components of the program. Secondly, the answers to open-ended questions from students were divided into four main categories: the three above and 4) comments about the tutors. As the tutor categories were further examined, the overlap of the responses about the management of the program and the components of the program resulted in their consolidation into a single category. The tutor and student comments were examined separately at first for themes within each group. Then the responses were reexamined for themes that were common to both sets of responses.

Results

Validity and Reliability of the MPE

Almost all syllabi for Precalculus and Engineering Calculus I referenced the department course page for the schedule of topics addressed; the remaining syllabi duplicated the information on the department course page. The expert panel confirmed that all but one question on the MPE tested material that was taught in Precalulus and used in Engineering Calculus I. That question was omitted from further analysis of the MPE scores. Although many other items could be candidates for testing for calculus success and many other topics in precalculus are not tested, the items on the MPE were determined to be a good subset of questions for a placement test for college Precalculus or Engineering Calculus I at Texas A&M University. The content validity for the MPE was determined to be high for measuring the knowledge of precalculus needed for calculus.

The mean (on a 4-point scale) grade point average (GPA) for Engineering Calculus I for the fall of students who participated in the summer program was 1.49 (*SD* = 1.228). Of the 68 who took Engineering Calculus I in Fall 2011, 51.5% completed the course with a grade of A, B, or C, which is necessary to continue on to Engineering Calculus II. However, success in Engineering Calculus II is much more likely for students who make an A or B in the previous course; 27.9% of the 68 who took Engineering Calculus I in Fall 2011 successfully completed the course with a grade of A or B.

Best reporting practices include reporting effect sizes with confidence intervals, (Capraro & Capraro, 2002; Capraro, 2004; Henson et al., 2001). Results for reliability of scores from 2008 through 2011, as measured by Cronbach's alpha were presented in Table 8. The reliability coefficient was close to 0.9 for the scores each year 2008 through 2011, and cumulatively. The reliability was not expected to change much as long as the test is given to the same types of entering freshmen, primarily those who are considering entering STEM majors. Although the F statistic, with p values is often reported for Cronbach's alpha, they were not used here because the sample sizes were quite large overall and in many of the subgroups as well (Thompson & Snyder, 1998). As Thompson (1992) so plainly expressed the problem,

> Statistical significance testing can involve a tautological logic in which tired researchers, having collected data from hundreds of subject, then conduct a statistical test to evaluate whether there were a lot of subjects, which the researchers already know, because they collected the data and know they're tired (p. 436).

For the data in this study, it was more appropriate to give the confidence intervals around the reliability coefficient. For wide confidence intervals, especially with sample sizes that are not small, the point estimate may not be very precise (Thompson, Diamond, McWilliam, Snyder, & Snyder, 2005).

Table 8
Reliability Estimates for 2008-2011

Year	2008	2009	2010	2011	2008-2011	CI (2008-2011)
Cronbach’s Alpha	0.888	0.882	0.892	0.892	0.889	[0.886, 0.892]

Cronbach’s alpha for the cumulative years 2008 through 2011 for males and females were very close (see Table 9). All ethnic groups had scores that showed high internal consistency, above 0.8, as shown in Table 10.

Table 9
Cronbach’s Alpha by Gender

	Cronbach’s Alpha	N	CI
Female	.889	3972	[0.884, 0.894]
Male	.886	7791	[0.882, 0.889]

Table 10
Cronbach's Alpha by Ethnicity

Ethnicity	Cronbach's Alpha	N	CI
Black	.887	375	[0.869, 0.902]
Hispanic	.886	2096	[0.879, 0.893]
American Indian	.918	34	[0.873, 0.953]
2 or more, not Black or Hispanic	.884	276	[0.864, 0.903]
Native Hawaiian	.830	22	[0.709, 0.917]
Asian	.872	766	[0.859, 0.885]
International	.881	178	[0.854, 0.905]
Unknown	.889	15	[0.789, 0.956]
White	.884	8000	[0.880, 0.887]

When analyzed by the college in which students were enrolled, all of the α values were above 0.84 (see Table 11). Scores for students in the Exchange Program had a lower α (0.600) and a wide 95% CI. However, the number of students was 7, and small sample sizes can have an adverse effect on the accuracy of any statistic. The MPE was designed to place students in STEM fields into either precalculus or engineering calculus, which are not courses normally taken by students in schools that focus on areas not related to STEM education. For that reason, and because there are large numbers of students in the Colleges of Engineering, Geosciences, Science, and Liberal Arts, reliability was analyzed by major in each of those departments (see Tables 12-15).

Table 11
Cronbach's Alpha by College

College	Cronbach's Alpha	N	CI
Agriculture	.883	178	[0.873, 0.892]
Architecture	.849	404	[0.827, 0.869]
Business	.846	388	[0.823, 0.867]
Education	.847	637	[0.829, 0.863]
Engineering	.852	5082	[0.846, 0.857]
Exchange Program	.600	7	[0.009, 0.918]
General Studies	.869	361	[0.849, 0.888]
Geosciences	.877	1166	[0.866, 0.887]
Liberal Arts	.864	983	[0.851, 0.876]
Science	.880	1384	[0.871, 0.889]
Veterinary	.844	173	[0.808, 0.875]

Table 12
Cronbach's Alpha by Major in Engineering

Engineering Major	Cronbach's Alpha	N	CI
Aerospace Engineering	0.843	401	[0.820, 0.864]
Biomedical Engineering	0.920	580	[0.911, 0.929]
Computer Science & Engineering	0.882	260	[0.861, 0.902]
Electrical & Computer Engineering	0.873	424	[0.855, 0.890]
Chemical Engineering	0.832	628	[0.812, 0.850]
Computer Science	0.861	272	[0.836, 0.883]
Civil Engineering	0.824	571	[0.803, 0.844]
Electrical Engineering	0.847	463	[0.827, 0.867]
Industrial Distribution	0.854	258	[0.827, 0.879]
Industrial Engineering	0.835	348	[0.809, 0.859]
Mechanical Engineering	0.831	763	[0.813, 0.848]
Nuclear Engineering	0.842	172	[0.806, 0.874]
Ocean Engineering	0.810	84	[0.746, 0.864]
Petroleum Engineering	0.837	467	[0.815, 0.857]
Radiological Health Engineering	0.798	47	[0.706, 0.873]
Electronics Engineering Technician	0.862	176	[0.831, 0.890]

Table 13
Cronbach's Alpha by Major in Geosciences

Geosciences Major	Cronbach's Alpha	N	CI
Environmental Geosciences	0.893	170	[0.869, 0.915]
Environmental Studies	0.795	57	[0.710, 0.864]
Geography	0.818	28	[0.706, 0.902]
Geology	0.871	76	[0.826, 0.909]
Geophysics	0.884	33	[0.819, 0.934]
Meteorology	0.803	88	[0.739, 0.858]

Table 14
Cronbach's Alpha by Major in Liberal Arts

Liberal Arts Major	Cronbach's Alpha	N	CI
Anthropology	0.895	32	[0.835, 0.941]
Classical Studies	0.819	3	[0.293, 0.995]
Communication	0.880	40	[0.820, 0.928]
Economics	0.862	126	[0.825, 0.895]
English	0.890	91	[0.855, 0.920]
French	0.822	6	[0.529, 0.971]
German	0.885	2	[0.361, 1.000]
History	0.844	95	[0.795, 0.886]
International Communication & Media	0.883	85	[0.844, 0.916]
Music	0.865	10	[0.709, 0.960]
Philosophy	0.946	18	[0.902, 0.976]
Political Science	0.865	85	[0.820, 0.903]
Psychology	0.835	232	[0.803, 0.864]
Russian	0.543	6	[-0.212, 0.924]
Sociology	0.830	128	[0.785, 0.870]
Spanish	0.826	24	[0.709, 0.912]
Telecommunication Media Studies	0.890	18	[0.802, 0.951]
Theater Arts	0.897	6	[0.727, 0.983]
University Studies Liberal Arts	0.758	2	[-0.341, 1.000]
Women's & Gender Studies	0.831	7	[0.583, 0.965]

Table 15
Cronbach's Alpha by Major in Science

Science Major	Cronbach's Alpha	N	CI
Applied Mathematical Sciences	0.853	113	[0.811, 0.889]
Biology	0.879	703	[0.866, 0.891]
Molecular & Cell Biology	0.833	57	[0.764, 0.889]
Chemistry	0.841	174	[0.805, 0.873]
Mathematics	0.871	144	[0.839, 0.900]
Microbiology	0.845	61	[0.784, 0.896]
Physics	0.740	84	[0.663, 0.814]
Mathematics for Teaching	0.837	11	[0.660, 0.948]
Zoology	0.890	37	[0.832, 0.935]

Because the MPE was a test including algebra and precalculus skills requisite for Engineering Calculus I, items were expected to be correlated. For exploratory factor analysis (EFA), the SPSS default of principal components was selected because the number of items was greater than 30, thus likely giving the same results as principal factor analysis (Thompson & Daniel, 1996). Oblique rotation was chosen because items were believed to be correlated (Henson et al., 2001). The eigenvalues and percentage of variance were given in Table 16 for components with an eigenvalue greater than one. The scree plot in Figure 3 confirms visually the likelihood of only one factor for the MPE.

Table 16

Eigenvalues and Percentage Variance for Components in MPE

Component	Eigenvalue	Percent of Variance
1	7.428	23.212
2	1.333	4.166
3	1.089	3.402
4	1.012	3.164

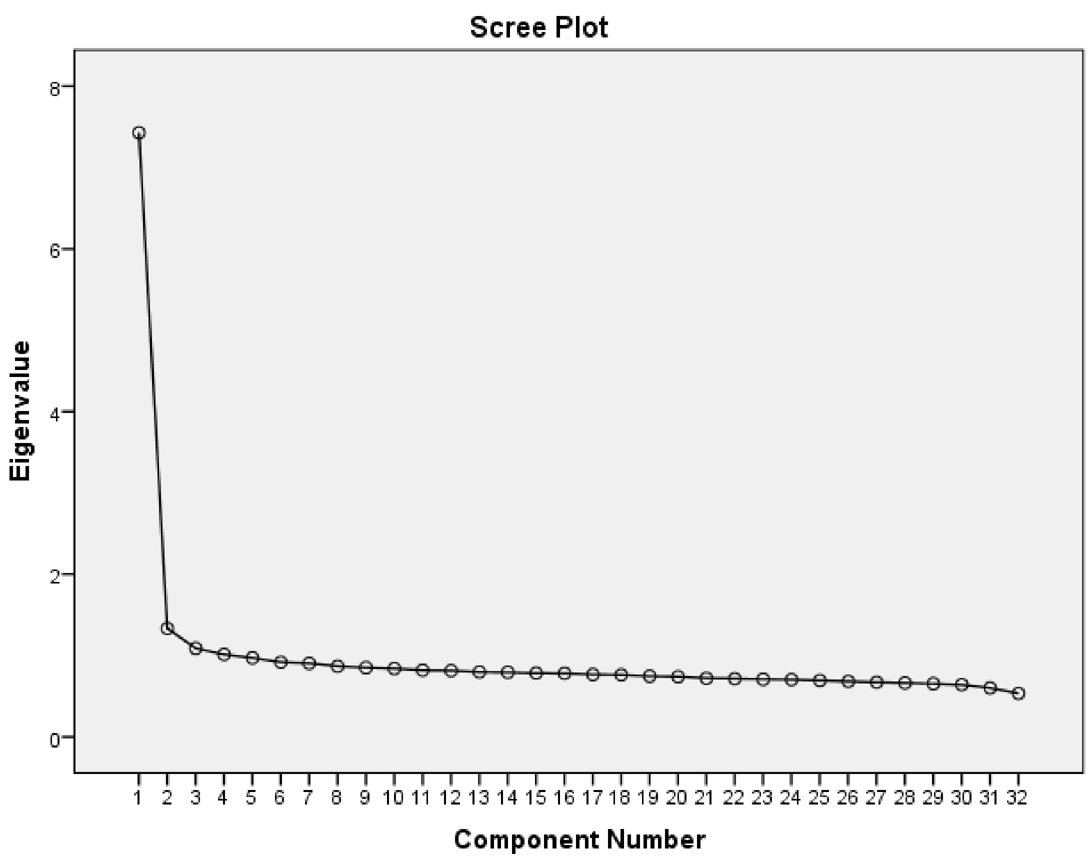

Figure 3.
Scree plot for EFA of MPE.

PPP and MPE Scores

The initial scores of the 122 students who participated in the PPP and retook the MPE before beginning classes in the fall had a mean of 18.44 (*SD* = 1.81). When students retook the MPE, the mean was 24.89 (*SD* = 4.01). The *SD* increased considerably after the intervention because only students with scores between 16 and 21, inclusive, were invited to participate in the PPP, but scores after the PPP could go as high as 33. The Hedge's *g* effect size was 2.068, with CI at the 95% level, [1.757, 2.379].

The mean GPA for Engineering Calculus I for the fall for students who participated in the summer program was 1.49 (*SD* = 1.228), but 51.5% of the 68 who took Engineering Calculus I in Fall 2011 completed the course with a grade of A, B, or C, which is necessary to continue on the Engineering Calculus II.

Program Design and Management

Tutor responses.

> I have honestly enjoyed the students and the tutoring. I was not sure how the on-line would work, but I feel in some ways it is even more effective than in person. The students do not feel pressure from their peers, there is better wait time, and the students are comfortable when working.

Tutors were very favorably impressed with the program overall. They liked the flexibility of the schedule from their standpoint and the student standpoint. Students could work through the online problems at their own pace. However, online meeting times were set for the students to meet with their tutors, at time most convenient for the majority of the assigned group. There was a desire for additional ways to contact students besides email, particularly the ability to call them to check on them if they did not attend sessions. Some tutors were interested in being able to check the progress of their students after they began their course work at the university. Although they commented that they would like to have some face-to-face time with their students, most tutors thought the online environment provided was sufficient for teaching the concepts. Another common thread through the comments was the personal touch provided in the program with the tutors responsible to work with small groups of students. They believed that access to a mathematics teacher, in addition to the online videos, textbook, and practice problems were strengths of the program.

Most of the comments about improvements to the management of the program related to student behavior and lack of self discipline. Students did not feel required to complete the practice problems assigned in the online homework system. Several tutors also commented on the fact that the rigor of the program helped some students realize that were not as proficient in their mathematical knowledge and skills as they had thought, and that they needed some preparation to be successful in college mathematics. One tutor wrote, “One student remarked that he learned more in this program than he did in high school.”

Student responses. “It broke down every section in the chapters, and pinpointed exactly where you had problems” was one positive expression of the effectiveness of the program design. They were very positive about the online environment in general. In particular, they liked the flexibility and being able to work from home. Quite a few students asserted that they would do better in a face-to-face classroom, but a lot of students also thought the online environment was more conducive to their learning. Several similar comments to this one were given: “I feel that I learn better face to face but I did learn a lot and I feel the program was very helpful.” Two reasons given for equal or greater success in the online program were “I felt it was able to be much more one-on-one, and much more interactive” and “if I ever misunderstood or forgot how to attack a problem, I could always go back to the recording and view class all over again.” Students appreciated the histogram bars that showed their progress through the program and the ability to work similar problems to those they missed through the online quizzes. They believed the Personal Study Program (PSP) helped them target weak areas for practice. Several students experienced technical difficulties at the beginning of the online program. In addition, they had trouble entering mathematical expressions correctly in free response boxes. Other negative comments included the time commitment and amount of work necessary to complete the program. The online program was designed to keep the highest score on quizzes, but several students experienced lowering of their scores when they continued to work on a section. An important suggestion by students was that they be able to go back and see the problems they missed and the correct answers after they closed out the quiz instead of having to print them out right then. Almost all students who had negative comments about specific features of the program were complimentary of the program overall. Except for email access to the tutor, each of the program components was listed by some students as the most effective, but the online tutoring was the most popular component. Students liked the email access, but they said they did not use it for asking mathematics questions. They saved those for the tutoring sessions. Several students expressed similar statements to "I like how many different media were available for students such as textbook, or video, because everyone has a method they learn best with."

Students had fewer comments about the program management than did the tutors. A few of them found the tutoring time slots inconvenient with their work schedules. Several commented that technical issues for tutors and students should be worked out before sessions began. One student suggested that online sessions be held several days after the online homework was assigned so that they could work more on their own before asking the tutor for help. The independent learning style implied in the suggestion seemed to be shared by very few students because, when asked about components of the program they liked best, many of them stated that they learned best from having a teacher explain and work examples and did not use very many of the other resources. Survey questions about program management led to questions about the program materials and content themselves.

Program Materials and Content

Tutor responses.

> The content is great. It could use another example or two on some topics, but overall, it doesn't need any changes. I'm quite impressed with how well you've stripped down precalculus to the essential things they need to know for calculus.

There were many positive comments similar to the one above and several constructive criticisms of the program materials and content. Tutors commented favorably about the variety of resources (videos, practice problems, textbook, tutoring) available in the online program. For example, one tutor had taught in the pilot program the previous year and commented on the increased number of sections of material that allowed her to better assess on which material the students needed to work. Another especially liked the rigor involved in the problems students were asked to solve.

There were several suggestions for improvement in the materials and content. Tutors noted that the order of some of the topics could be changed so that the more difficult material came later in the sequence. It was also suggested that some worksheets that pertain to the algebraic manipulations used in calculus be added for students to see examples of the work they would be required to do without a calculator in the future calculus class. Several noted that there were a few notation issues in the online problems, that a few more examples should be added in a few areas in the textbook and videos. One wanted to see more multiple choice questions on the quizzes instead of students typing in answers.

A number of difficulties with the online homework system were reported by tutors. There were two main types of problems: 1) students' inability to enter the correct notation, and 2) glitches in the newly revised personalized study plan (PSP). High school students had not experienced online homework systems and did not know how to enter some of the notation in the spaces in which they typed answers. Some frustration occurred as a result, but one tutor said that the problem improved quickly. They commented that students reported that online homework system pop-up boxes sometimes failed to appear, the system froze in the middle of a practice, and they could not access some quizzes and tutorials. However, the problems were quickly resolved by the provider of the online homework system.

Student responses. "I liked being able to take quizzes, see what ones I missed, then get to do problems that were similar to figure it out" was one of many positive comments about the materials in the PPP. However, the students in the program often found the problems in the online quizzes more difficult than they had experienced previously, and sometimes more so than the ones used in the tutor sessions. One student thought "some of the questions were outrageous." On the other hand, another student commented, "The chapter quizzes gave good, representative problems to learn the important area of math I need for calculus." A few students felt that there should be closer alignment between the videos and the problems in the chapter quizzes.

Tutors

"My professor was an excellent teacher" expressed almost every student's opinion of the tutors. They were asked about the most helpful and least helpful things the tutors did. The vast majority of students commented that their tutors were great and specified that they explained concepts well, answered all student questions, and made sure all students understood the material. Adjectives used to describe the tutors included "awesome," "excellent," "very good," "great," "patient," and "encouraging." Other common positive comments included the interactivity of the tutoring sessions, the ability to work in breakout rooms individually or with another student, tutors offering to work with them individually outside the regular sessions, discussing different ways of solving a problem, using more rigorous sample problems like the ones in the online system, and staying on schedule. As one student explained, “She would work out and explain difficult problems, and she kept it interactive which helped keep everyone involved and learning.”

Quite a few students either stated that there was nothing “least helpful” that the tutor did or simply did not comment on that portion of the survey question. The most common negative comments were 1) going through the material a little too fast, 2) lag time waiting for other breakout rooms to finish the problem(s), and 3) failing to debrief problems in the main room where the conversation is recorded created a concern for students watching the session later. Other comments that were infrequently mentioned included using examples easier than the ones in the online practice problems, minor difficulties tutors had with the technology, having students work on problems before explaining in detail, working on some calculus at the end of the program (because calculus was not on the MPE), giving homework problems without answers to check, going over time a little bit on occasion, and occasionally getting off topic. One student commented that more time was needed to focus on trigonometry and logarithms in more depth.

Conclusion

The MPE scores for 2008 through 2001 were determined to be valid and reliable for placement of students into precalculus or calculus, for both genders, all ethnic groups, and colleges with STEM majors. Students who participated in the PPP improved the MPE scores considerably. Of the 122 students, 99 (81%) raised their scores above the cutoff and were allowed to enroll in Engineering Calculus I in the fall, if desired. The next step is to determine whether the students are at least as successful as students who chose to take Precalculus before calculus instead of participating in the PPP.

As a result of the analysis of survey responses from tutors and students, several changes will be made to the Personalized Precalculus Program (PPP). Firstly, the mistakes discovered by the tutors will be corrected. Secondly, the additional problem videos and worksheets suggested by tutors will be provided and integrated into the system. The program was not expected to be fully developed yet; creating videos for all of the subsections and types of problems takes a considerable amount of time. It was expected that videos would need to be expanded, and the results of the surveys will help determine the areas of highest need. Thirdly, the sequencing of the material will be reviewed to see whether a better sequence can be determined and implemented. There will not be an increase in the number of multiple choice questions because students in the calculus classes at the university will have free response questions on their exams as well as in the online homework system.

Analysis of responses to the survey questions that were not specifically asking about what should be done to improve the program also provided some insight into ways to improve the program. Tutors previously had to come up with their own examples to use in the tutoring sessions and to assign for practice outside the online system. Sometimes the problems they used were not as rigorous as those in the online quizzes, and sometime they used problems directly from the online quizzes. Problem sets with solutions for tutors to use as examples and to assign students will be provided so that the problems will match the rigor of the online quizzes and students will have answers to make sure they are getting them correct as they practice.

Insight into students' technology knowledge and experience was gained from the survey responses. Although today's students are much more technology capable in many ways, students had some difficulties with the educational environments used in the summer program, some of which will be used by students when they enroll in credit mathematics classes at the university. Because of the insights gained, plans include surveying students after taking college mathematics courses to determine whether an unexpected benefit to the summer program is the experience and familiarity with the technology they will use in college.

CHAPTER IV

REMEDIATING STUDENTS' PRECALCULUS SKILLS TO INCREASE ENGINEERING CALCULUS I SUCCESS

Introduction

With the goal of increasing success in Engineering Calculus I and subsequently engineering majors, the Department of Mathematics at Texas A&M University, through a grant from the National Science Foundation, established a summer program to bridge high school mathematics knowledge to requisite mathematics knowledge for Engineering Calculus I. Of the students who participated in the summer program, 81% raised their scores on the mathematics placement exam (MPE) and were cleared to register for Engineering Calculus in the fall. Students who did not raise their score above 21 out of 33, whether or not they participated in the summer program, had to take Precalculus before enrolling in Engineering Calculus I. Because Precalculus is primarily taken as a prerequisite for Engineering Calculus I, the purpose of the course is to remediate mathematics skills needed for the calculus course.

Remediation for College Level Mathematics

Remedial education has been a topic of concern for many years for a variety of reasons. Community colleges have provided the bulk of remediation for reading, writing, and mathematics below the level of College Algebra, but 4-year universities also offered a considerable amount of remediation. In fall 2000, 22 percent of freshmen entering U. S. colleges and universities took remedial mathematics courses (Parsad & Lewis, 2003). In fall 2006, 38 percent of students at public two-year colleges and 24% of students at public four-year colleges took remedial courses. Remedial mathematics courses had the highest enrollment of the three areas: reading, writing, and mathematics. In Texas, in fall 2003, more than 65,000 students were enrolled in remedial mathematics courses (Terry, 2007). Between 1995 and 2000, U. S. postsecondary institutions that limited the length of time students could remain in remediation because of state policy increased from 6 to 27 percent (Parsad & Greene, 2003).

However, students whose skills are below the college credit level were not the only ones in need of remediation. Students who aspired to major in Science, Technology, Engineering, and Mathematics (STEM) fields were often not prepared for the rigors of calculus, which was usually the introductory college mathematics course expected for those students.

Costs of Remediation

Education cost. Over the five years from 1995-2000, the percentage of entering freshmen enrolled in remediation did not increase, but the percentage of students who spent more than one year in remediation increased from 28 percent to 35 percent (Parsad & Greene, 2003). Some policyholders and taxpayers have become concerned about the fact that they paid twice for the same education when students needed remediation for knowledge they should have gained in high school. The average cost for one credit hour for remedial education in Texas in 2005 was $164. The Texas Legislature allocated $176 million for remediation in postsecondary institutions in the 2000-2001 academic year (Hammons, 2005) and $206 million in the 2006-2007 biennium (Terry, 2007). One estimate of the total cost, including tuition, fees, and local taxes for the 2000-2001 year was $462 million (Hammons, 2005). Higher education costs have continued to rise. In the fall of 2011, nationwide, costs rose 8.3% from the prior year (CBS Interactive, 2011).

Loss of earnings cost. Besides the cost of tuition and fees for remedial education, there are costs to students, their families, and the economy. In 2006 it was estimated that in the U. S. $2.3 billion per year was lost from earnings because "remedial reading students are more likely to drop out of college without a degree, thereby reducing their earning potential" (Alliance for Excellent Education, 2006, p. 1). Nationwide, it was estimated that a college graduate could expect to make, on average, $1.2 million more in wages over his or her lifetime than a non graduate (Terry, 2007).

Time cost. When students spent time completing remedial mathematics before they could take the mathematics required for their degree plans, the time to graduation was longer, and the probability of completing a degree less likely. Nationwide, only 20 percent of students who completed remedial programs were expected to earn a 4-year degree within six years, while close to 50 percent of students overall were expected to graduate in six years. In fact, it was found that the need for remediation was the leading predictor of whether or not a student dropped out of college (Terry, 2007). For engineering majors at Texas A&M University, students were required to be enrolled in Engineering Calculus I concurrently or prior to the first engineering course. Students who needed to take Precalculus after entering the university were at least one semester behind in a rigorous degree plan that did not have opportunities to catch up in the sequence into upper level engineering courses.

Remedial Distance Education

Distance education has become a way to offer education more cost effectively to more students, and colleges and universities have offered more remedial courses by distance education in recent years. Between 1995 and 2000, the percent of U. S. colleges and universities that offered remedial courses via distance increased from 3% to 13%. The most common mode of delivery was asynchronous, computer- based instruction in fall of 2000 (64%) (Parsad & Greene, 2003). In addition to the use of technology, the Virginia Community College system designed a modular program for remediation for implementation in 2012. The model was developed with the hope that each student would be able to remediate specific weaknesses, and thus shorten the time required to complete remediation and move on to college level coursework (Driscoll, 2011).

Effectiveness of Remediation

There is considerable disagreement about the effectiveness of mathematics remediation. Many factors contribute to the difficulty in determining the effectiveness, some of which are differences in college curriculum, instructor differences, socio-economic status of students, and whether remediation is required or voluntary. Some studies have shown higher retention and approximately equivalent success rates for remediated students compared to those who required no remediation. Other studies indicated that remediation was detrimental to success, and some show that it had a negative effect in certain instances and positive in others (Bettinger & Long, 2009; Melguizo, Bos, & Prather, 2011). In particular, students who began their remedial work at the highest level performed similarly to students who did not take remediation

(Pearley, 1995; Rokso, Jenkins, Jaggars, Zeidenber, & Cho, 2009). For students whose degree plan required calculus, students who needed remediation of precalculus before taking calculus graduated after four years at a rate of about 70 percent, compared to 80 percent for students who placed directly into calculus (Waits & Demana, 1988). In 2007, the Texas Higher Education Coordinating Board funded eight developmental summer bridge programs. Participants in the programs were more likely to pass credit courses in the fall in writing and mathematics (Warthington, Barnett, Weissman, Teres, Pretlow, & Nakanishi, 2011). However, mathematics preparation did not explain all the variance in level of success for students in college mathematics.

Effect of Study Skills on College Success

One of the factors important in college success was study skills. Students with composite ACT scores in the 12 to 15 range and 28 to 31 range managed to succeed in high school without much studying, but discovered that college was quite different (McCausland & Stewart, 1974). For undergraduate students, study skills accounted for about 15% of the variance in grades. On average, students performed 50 – 58% of appropriate behaviors associated with study skills. Common deficiencies in study skills included note-taking, time management, reading skills, and waiting too late to study for an exam. Many colleges have implemented courses designed to help students build study skills, but the success of such programs is mixed (Lammers, Onwuegbuzie, & Slate, 2001).

Based on the meta-analysis of several studies, greater faculty involvement was needed to ensure success of programs to improve study skills. Student supports needed to be integrated into the specific courses so that strategies pertinent to the subject area could be addressed. Students who needed support most were usually reluctant to investigate and use resources. Faculty could have helped encourage students who needed help by making all students aware of the resources available to them (Bailey, 2011).

Methodology

Participants

Students in their first semester at Texas A&M University were required to take the MPE before enrolling in Engineering Calculus I. Students who took the MPE in spring or early summer 2011 and scored 16 to 21, inclusive, were offered the opportunity to take the summer intervention to try to raise their scores to at least 22 so that they could enroll in Engineering Calculus I in the fall and stay on track with the engineering course sequence. The 275 students who scored 16 to 21, inclusive, on the MPE and enrolled in Precalculus or Engineering Calculus I in Fall 2011 or Engineering Calculus I in Spring 2012 were the participants for the study. Of the entry level traditional college freshmen, between 18 and 19 years of age, participants, 63 were female, 212 were male. There were 67 Hispanic, 179 White, 10 Black, 11 Asian, 1 American Indian, 5 Mixed (excluding Black and Hispanic), and 2 International.

Data Analysis

The question of interest was: Were students who scored 16 to 21, inclusive, on the MPE before they participated in the PPP approximately as successful in Engineering Calculus I as the students who scored 16 to 21, inclusive, and took Precalculus before Engineering Calculus I? The strongest research design for this study would have been one in which students with scores 16 to 21, inclusive, on the MPE were randomly assigned to the summer PPP or to Precalculus in the fall. The resulting difference, if any, in outcome would most likely be attributable to the difference in treatment (Shadish, Cook, & Campbell, 2002). However, such a design would be ethically improper because students who participated in the summer intervention had the opportunity to begin the engineering sequence in the fall rather than waiting until the following spring and losing time in the path to a college degree. Therefore, all students with scores in the range of 16 to 21, inclusive, were offered the opportunity to participate in the summer program. The students who performed in the range of 16 to 21, inclusive, seemed to have the highest likelihood for success with a summer intervention program as compared to student who scored below this range because the interquartile range for all MPE scores from 2008 through 2012 was 16 to 23, and students who scored above 21 were allowed to register for Engineering Calculus I. Students who scored in the range from 16 to 21would have performed similarly in mathematics before college entrance and were likely have similar motivation and study skills and other factors that have impacted their mathematical performance before calculus. The pretest and any subsequent retakes of the MPE provide sufficient controls for comparing the two samples and estimating the impact of student performance in Engineering Calculus I.

Several unexpected paths to Engineering Calculus for students who scored 16 to 21, inclusive, became evident. There were six distinct variations with at least four students each (see Table 17). A one-way ANOVA with six levels was used to compare group means and test the hypothesis, H_0: $M_1 = M_2 = M_3 = M_4 = M_5 = M_6$, where M_i, (i =

1, 2, 3, 4, 5, 6) was the mean course grade (on a 4-point scale) of the students for Engineering Calculus I for each group. Because the design is not balanced, it cannot be assumed that main and interaction hypotheses would be uncorrelated, and overlapping effects would have occurred (Thompson, 2006). The α level was set to the typical of .05, and Tukey post-hoc tests were invoked for pair-wise comparisons between the groups. Effect sizes were computed for each comparison, and confidence intervals reported (Capraro, 2004; Capraro & Capraro, 2009).

Table 17
Levels for One-Way ANOVA on Engineering Calculus I Course Grades

Level	N	Description
1	69	PPP participants who raised scores to 22 or higher and enrolled in Engineering Calculus I Fall 2011
2	12	PPP participants who took Precalculus Fall 2011 and Engineering Calculus I Spring 2012
3	4	PPP participants who did **not** raise scores to 22 or higher, but took Engineering Calculus I without taking Precalculus
4	168	Students who did not participate in PPP, took Precalculus fall 2011 and Engineering Calculus I Spring 2012
5	12	Students who did not participate in PPP, did not take Precalculus as required, and took Engineering Calculus I Fall 2011
6	10	Students who did not participate in PPP, did not take Precalculus as required, and took Engineering Calculus I Spring 2012

Results

Descriptive statistics were presented, followed by results of the one-way, six-level ANOVA. The means of Engineering Calculus I grades for the six groups were then provided, with *SD*'s, and CI's around the means. Percentage of students successfully completing Engineering Calculus I for each of the groups was reported.

Descriptive statistics were calculated to provide information about the numbers of students in each group, the means of the course grades (on a 4-point scale), and the standard deviations for each of the six levels (see Table 18). The mean course grades for the various groups appeared to be considerably different. The SD's for all groups were relatively large for mean course grades on a 4-point scale. The data were examined by gender, ethnicity, and major subgroups to see whether more information could be gained about where differences might occur. There were no patterns found that could provide a systematic explanation for the variance in performance. The *SD* for group 3 was large, and the CI was large, but N was small. The CI covered all possible course grades, which indicated that the point estimate was not precise and gives us no valuable information about the PPP students who took Engineering Calculus I without Precalculus even though they did not raise their scores above 21. Because participants self-selected the path, sample bias was present and likely responsible for large variance.

Table 18
Descriptive Statistics of Levels of Pathways to Engineering Calculus I

Level	N	Mean	*SD*	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
1	69	1.51	1.244	1.21	1.81
2	12	3.00	.953	2.39	3.61
3	4	2.50	1.732	-.26	5.26
4	168	1.92	1.278	1.72	2.11
5	12	.92	1.084	.23	1.61
6	10	2.60	1.174	1.76	3.44
Total	275	1.85	1.303	1.70	2.01

Effect of PPP on Student Grades in Engineering Calculus I

A one-way, 6-level ANOVA, was used to determine whether the group means were statistically significantly different. Tukey post hoc was then used to find out which means were statistically significantly different and which were not. Of particular interest was the comparison of the students who raised scores on the PPP above 21 and enrolled in Engineering Calculus I compared to students who followed a different pathway to Engineering Calculus I.

The first step in the 6-level ANOVA was to examine the homogeneity of variance for the model (p = .409); therefore, there was no statistically significance difference among the level variances. The omnibus F-test was statistically significant (p

$< .001$; $F = 5.412$), so the null hypothesis that the means of the groups were equal was rejected. The highest mean course grade (3.00) occurred in the group that participated in the PPP and took Precalculus before taking Engineering Calculus I, and the second highest mean course grade (2.60) was for the group that did not take Precalculus in the fall as required but took Engineering Calculus I in the spring.

Interpretation of Individual Means and CI's. The Tukey post hoc pairwise comparison indicated that the mean course grade for PPP participants who took Precalculus in fall 2011 and Engineering Calculus in spring 2012 was statistically significantly different from the mean course grade for all other groups except the two groups that took Engineering Calculus I in the fall without taking Precalculus as required. In addition, the mean course grade for the two groups that did not take Precalculus as required were statistically significantly different, with the group that took Engineering Calculus I in the spring earning higher grades. Figure 4 shows a plot of the mean course grades for each of the groups for the six levels of the ANOVA. The mean course grades for Levels 2 and 5, the highest and the lowest, seemed to be most different from the other means. The group that participated in the PPP and took Precalculus before Engineering Calculus I had the highest mean course grade, and the group that did not participate in the PPP or take Precalculus but took Engineering Calculus I in the fall had the lowest mean course grade. Level 3, which represents the PPP participants who did not raise scores above 21 but took Engineering Calculus I without taking Precalculus had a wide CI (see Figure 3). In fact, the CI covered the entire range of possible course grades, meaning there was no precision in the point estimate. Levels 1 and 4 had small confidence intervals, which indicated more precision in the point estimate. Larger sample sizes with relatively less variance contribute to a smaller confidence interval. The 95% CI did not indicate 95% certainty that the CI captured the population mean, but that 95% of infinitely many CI's around means from samples would capture the population mean (Cumming & Finch, 2005; Thompson, 2006) and that there was approximately 83% probability that another sample would fall within the CI (Cumming, Williams, & Fidler, 2004; Cumming, 2008). Thus, the CI's for Levels 1 and 4 gave a good picture of what could be expected for future samples, with a small range of course grades. They had the largest samples sizes, which contributed to the small CI's. The CI's for Levels 2, 5, and 6 were medium width, indicating a moderate level of precision and a little larger range of course grades that would be expected. Sample sizes were 10 to 12, contributing to the larger CI and smaller precision.

Comparison of Means and CI's. The plot with CI's around the means (see Figure 5) also clearly indicated which means were statistically significantly different. According to the "rules of eye" for interpretation of 95% confidence intervals, for sample sizes of 10 or more, an overlap of one-half an arm (distance from the point estimate to the upper or lower bound of the confidence interval), is approximately equivalent to a *p*-value of 0.05; intervals just touch are approximately $p = 0.01$, and a gap indicates $p = 0.001$ (Cumming, 2009; Cumming & Finch, 2005). Level 1 (PPP participants who raised MPE scores above 21 and took Engineering Calculus I fall 2011) and Level 2 (PPP participants who took Precalculus in fall 2011 and Engineering Calculus I spring 2012) had CI's that did not overlap, indicating that they are statistically significantly different. Levels 4, 5, and 6 are all students who did not participate in the PPP. Levels 4 and 5 and Levels 5 and 6 do not overlap, but Levels 4 and 6 do overlap more than half an arm's length. Thus, for students who did not participate in the PPP, grades of students who took Precalculus in the fall and Engineering Calculus I in the spring were different from grades of students who did **not** take Precalculus but took Engineering Calculus I in the fall. The grades of students in the non-PPP group who did not take Precalculus were different for those who took Engineering Calculus I in the fall and those who took Engineering Calculus I in the spring. For non-PPP students who took Engineering Calculus I in spring 2012, the CI's overlap, indicating that grades for those who took Precalculus before Engineering Calculus I and those who did not were not very different.

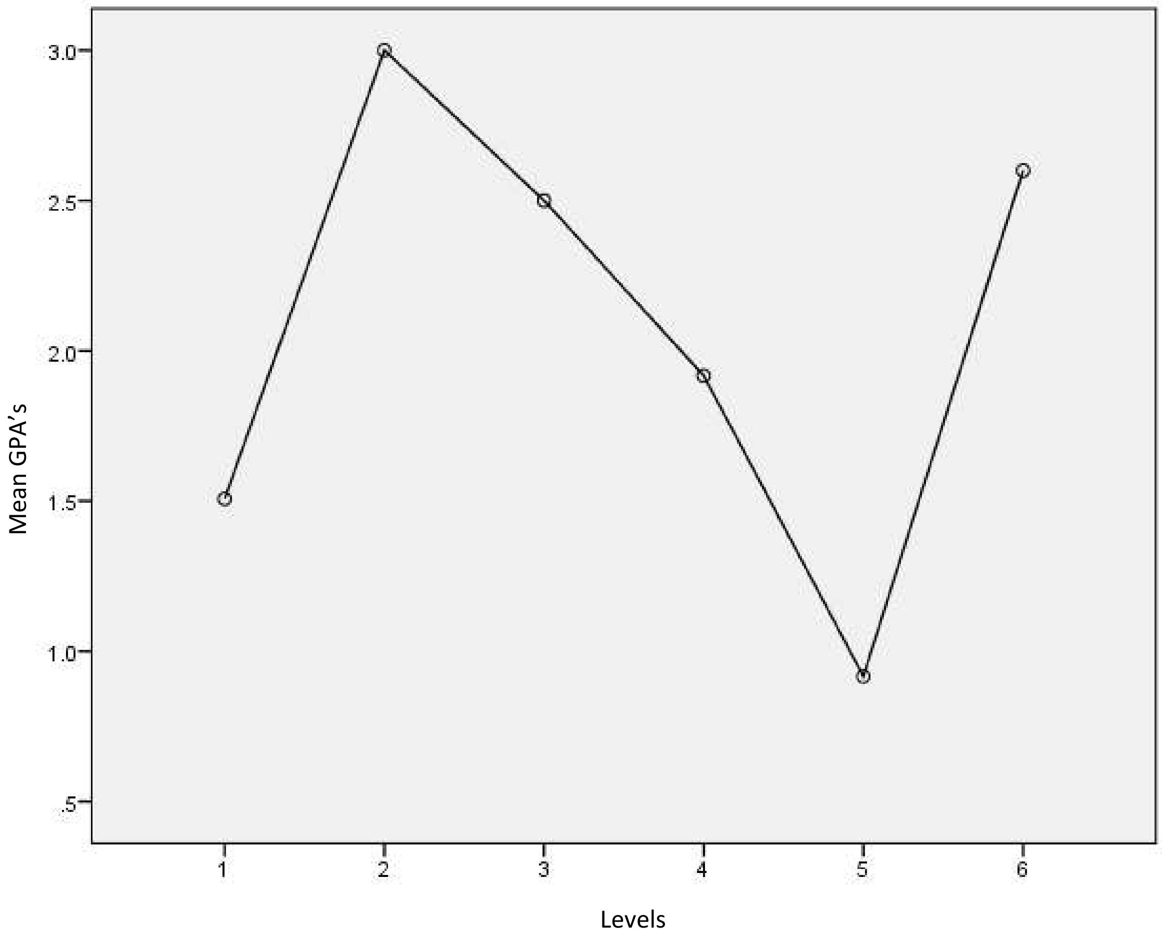

Figure 4.
Plot of mean course grades of students in each level of the ANOVA.

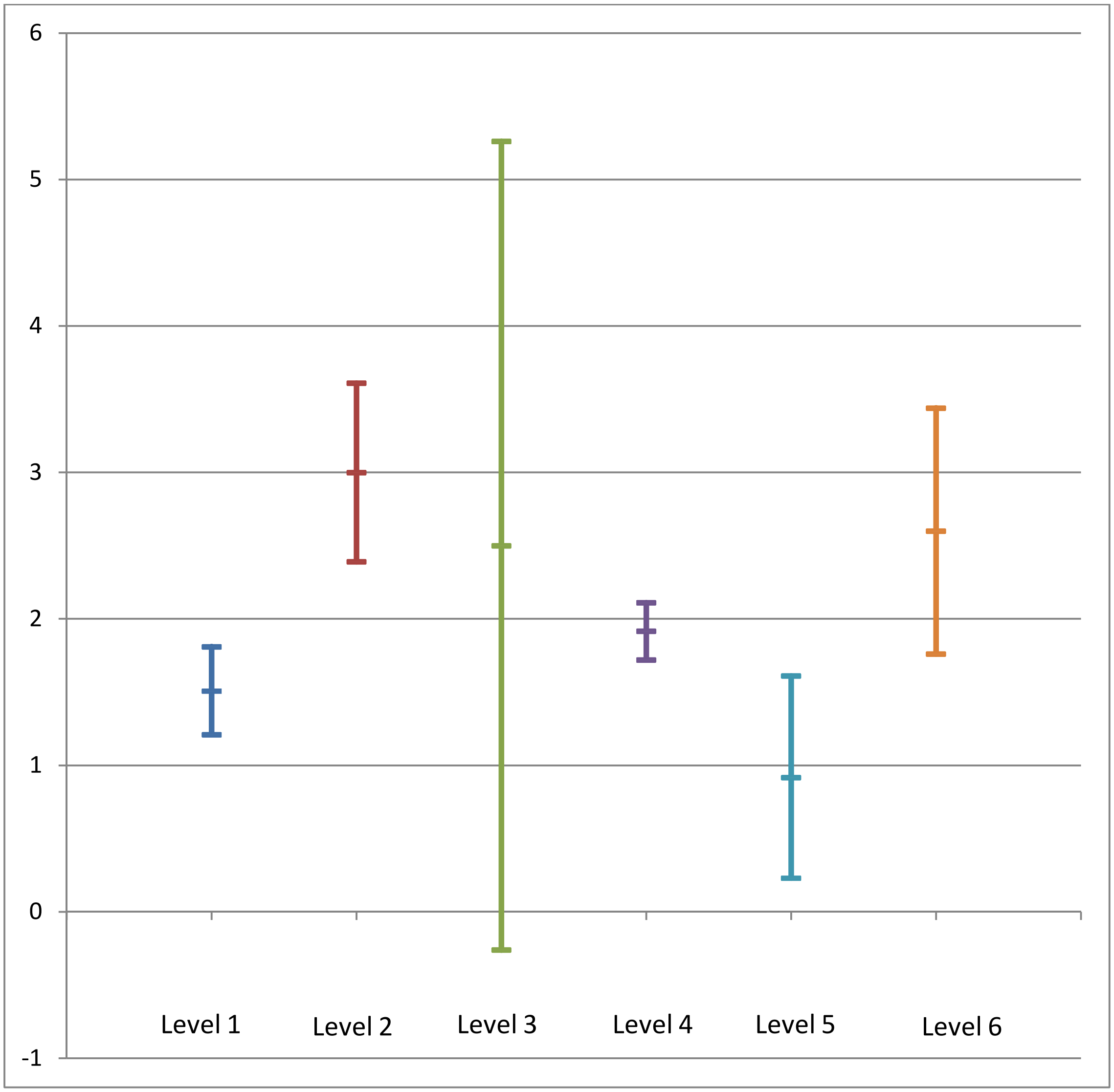

Figure 5.
Confidence intervals around mean course grades of students in each ANOVA level.

For the pairwise comparisons, Hedge's *g* effect sizes were computed to quantify the differences with a standard measure for comparison. Table 19 contains the effect sizes and confidence intervals. There were several large effect sizes (> .7), but not all were statistically significant ($p < .05$) or had large CI's. For example, Levels 1 and 3 had an effect size of .772, but p = .134 and the confidence interval [-2.44, 1.788]. On the other hand, three comparisons showed large effect sizes and smaller confidence intervals. PPP participants who raised scores high enough to enroll in Engineering Calculus I (Level 1) and PPP participants who took Precalculus before Engineering Calculus I (Level 2) had a small p-value and relatively small CI. A similar relationship was found for the comparison of PPP participants who took Precalculus before Engineering Calculus 1 (Level 2) and nonPPP students who did not take Precalculus but took Engineering Calculus I in the fall (Level 5). Also statistically significant with a large effect size was the comparison of 1) nonPPP students who took Engineering Calculus I in the fall (Level 5) and nonPPP students who took Engineering Calculus I in the spring (Level 6) and 2) nonPPP students who did not take Precalculus but took Engineering Calculus I in the fall (Level 5) and in the spring (Level 6). Figure 6 illustrates the results with a graph of point estimates for the comparisons that showed statistical significance, along with their confidence intervals.

Table 19
Effect Sizes and Confidence Intervals for Mean Differences

Levels Compared	Hedge's *g*	*p*	Confidence Interval
1 and 2	1.222	< .001*	[.581, 1.863]
1 and 3	.772	.134	[-.244, 1.788]
1 and 4	.322	.025	[.040, .604]
1 and 5	.478	.127	[-.140, 1.095]
1 and 6	.873	.011	[.196, 1.550]
2 and 3	.406	.469	[-.734, 1.546]
2 and 4	.853	.005*	[.261, 1.445]
2 and 5	1.968	< .001*	[.993, 2.942]
2 and 6	.361	.369	[-.445, 1.168]
3 and 4	.448	.375	[-.544, 1.441]
3 and 5	1.193	.046	[-.011, 2.398]
3 and 6	.069	.901	[-1.091, 1.229]
4 and 5	.786	.009*	[.194, 1.377]
4 and 6	.532	.103	[-.109, 1.172]
5 and 6	1.436	.002*	[.496, 2.376]

* These were statistically significant ($p < .01$).

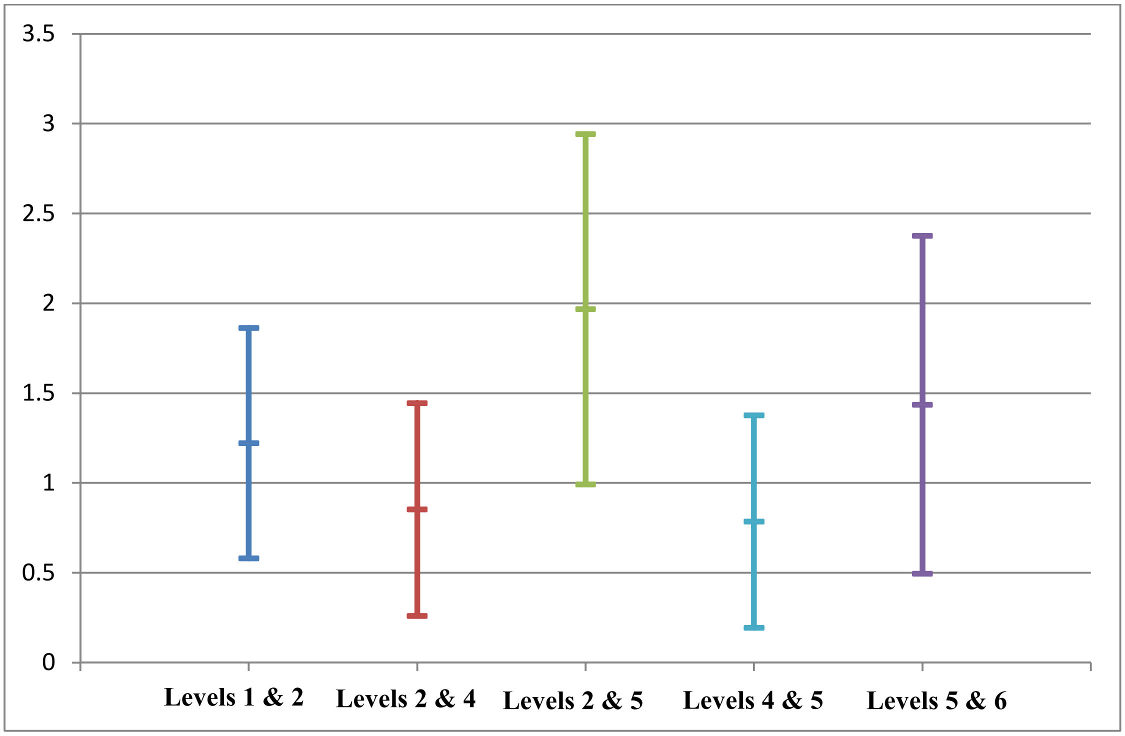

Figure 6.
Confidence intervals for statistically significant effect sizes.

Effect of PPP on Success Rates in Engineering Calculus I

Mean course grades of the students who chose different paths to Engineering Calculus I were not the only quantifiers of interest. The goal was to give more students access to success in Engineering Calculus I so that they could pursue their STEM majors, particularly in the College of Engineering, whose students are required to have taken or be enrolled in Engineering Calculus I in order to begin the engineering sequence. Students who complete Engineering Calculus I were considered successful because they were able to take Engineering Calculus II. Of the 69 students from the summer program who raised their MPE scores to 22 or above, 49% completed

Engineering Calculus I with a grade of A, B, or C, and 26% completed the course with a grade of A or B. Of the 168 students with MPE scores between 16 and 21, inclusive, who took Precalculus before Engineering Calculus I rather than participating in the summer PPP 65% completed Engineering Calculus I with a grade of A, B, or C, and 35% completed the course with a grade of A or B (see Table 20).

Table 20
Percent of Students in Each Group Who Completed Engineering Calculus I with A, B, or C

	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
% A, B, or C	49%	92%	75%	65%	33%	90%
% A or B	26%	75%	75%	35%	0%	0%

Discussion

While enrollment in Calculus I at U. S. postsecondary institutions remained fairly steady from 1980 through 2000, overall calculus enrollment dropped and precalculus enrollment increased. The precalculus course is generally considered a preparation for calculus, but its enrollment increase has not resulted in an increase in Calculus I enrollment, which indicates that it is not meeting the needs of the students who take it. In one university surveyed, less than one-third of the students who successfully completed precalculus enrolled in Calculus I. Precalculus was a filter that blocks students from reaching their educational goals (McGowen, 2006). In a Washington state study, only 11% of students who took Algebra II as the highest level mathematics course in high school were ready for college-level mathematics. However, student who earned an A in Algebra II were more likely to be ready, at the rate of 60%. Students who took Precalculus were also more likely to be college-ready (Stern & Pavelchek, 2006).

Enrollment in Engineering Calculus I followed a similar pattern to that found in calculus enrollment in the U. S. overall. Of the 99 students whose increase in MPE scores allowed them to register for Engineering Calculus I in the fall, only 69 actually registered for the class. At Texas A&M University, Precalculus is rarely taken for any purpose than to prepare for calculus because it is not one of the courses in the core curriculum. It operates as a remedial course and does not count toward any mathematics course for a degree plan. The participants of the summer PPP did not perform as well in Engineering Calculus I as the students who took Precalculus in the fall, but the difference was not statistically significant. The PPP students saved time and money by being able to begin the engineering sequence during the first semester of college enrollment. Results for the PPP participants who did not increase MPE scores to 22 or higher but enrolled in Engineering Calculus I were inconclusive. The mean course grade was higher than several other groups, but the CI covered the entire range of possible course grades. That group will be of interest in future semester to see whether more conclusive results can be obtained over time with possibly more students. Interestingly, there was a difference in success for students who bypassed Precalculus and took Engineering Calculus I in the fall or spring.

Overall, the students who took Engineering Calculus I in the spring performed better than those who took it in the fall. There are several factors that could have influenced the grades. One is the difference in instructors. However, the majority of instructors in the spring were experienced in teaching the course, and two of them had taught it in the fall as well. The three exams before the final exam are common exams written by the faculty teaching that semester. Because the faculty was experienced and most had taught the course in the fall and/or the previous spring, there was likely little difference in the expectations from the faculty. One common characteristic of students who took Engineering Calculus I in the spring was that they had experienced one semester of life at the university. The grades used in the calculations for this study were the grades from the first time the students took Engineering Calculus I. However, there were a number of students who took Engineering Calculus I in the fall and retook it in the spring. Considering the research on the effect of study skills on student performance, the results were not too surprising. When the next semester is complete, there will be additional analysis of data on students in each of the six levels to see whether the trends continue.

Beginning in summer 2012, students with scores below 16 will be allowed to participate in the summer program. Whether they are expected to need six weeks or a more extended period of time for remediation is unclear. Studies will continue to see what works best for the success of students with lower MPE scores to assist them in remediating skills before the fall and in a format that allows them to remain at home and continue their summer activities or jobs while building their mathematics skills to prepare for Engineering Calculus I. Additional supports will be implemented to assist students in study skills and other adjustments to the academic life at the university level so that they can be successful in their chosen fields.

CHAPTER V

SUMMARY AND DISCUSSION

Mathematics Remediation

Online personalized remediation seems to be the “wave of the future.” Most of the interventions to increase college calculus success discussed in Chapter II involved technology in some way. With the latest technological advances, there is much that can be done to customize learning for all students. Presently, software programs are being used to lead students through their mathematics learning. Virginia Community College System implemented a program in 2012 to customize remediation for their students so that each one can focus on his or her needs and be able to qualify for college credit mathematics quickly (Driscoll, 2011). However, that does not mean that teachers are no longer necessary. The results from one project that included many of the same components as the Texas A&M PPP indicated that online tutoring was a component that was lacking for increased success (Kennedy, 2007). Future programs should not try to eliminate instructors, but use them most effectively to increase student learning. Instructors will always be needed to answer questions students encounter they are unable to figure out on their own from written text, streaming videos, and/or problem examples and explanations. There are no easy answers to the problem of remediation, and there are numerous reasons the problem is so difficult to solve. One of the problems is that each student may have his or her own set of mathematical misconceptions that need to be addressed. One intervention involved confronting students with specific common misconceptions (Gruenwald & Klymchuk, 2003). Mathematical misconceptions are often deep-rooted and difficult to remove and correct (Allen, 2006; Nite, 2012). Teaching the correct concepts does not always uproot the misconceptions; they persist and may pop up at any time. A component to address misconceptions could be an effective addition to a personalized mathematics remediation program.

In addition to the use of technology in remediation and intervention programs, many college and universities are using placement exams. In the past, many have used SAT and ACT, and currently ACCUPLACER has been utilized widely. However, many institutions are finding that local placement tests do a better job placing students, particularly at the precalculus and calculus level. The Mathematics Placement Exam (MPE) at Texas A&M University is an example of an exam that has had high reliability over scores for at least four years. Results of an in-depth analysis was presented in Chapter II.

Precalculus and Calculus Success

Calculus has long been considered an impediment to some students pursuing STEM majors and careers. Precalculus has also been shown to be a roadblock for students aspiring to STEM fields (McGowen, 2006). Changes in teaching must occur from the earliest years of mathematical teaching and learning, through high school and even college to help students become successful in mathematics learning and allow them to pursue their dreams. With an ever increasing need for thinking skills and knowledge of mathematics, more students must access higher levels of mathematics. While more teachers are learning strategies to reach a greater variety of learners, interventions must be in place to help those who are able and willing to conquer the knowledge and skills needed but have not had the opportunity to do so. Interventions can be modified and fine-tuned to be more effective as more analysis of results is completed.

Remediation of algebra and precalculus concepts and skills is not sufficient to ensure student success at the college level. There is a major difference in the pace and expectations of a college mathematics class in comparison to a high school mathematics class. In fact, the entire college experience is very different from the high school experience. For example, much time in high school is devoted to socializing and involvement in sports activities, both during the school day and in the evenings. Students often spend little time outside the school day studying (Zelkowski, 2011). The pace during the day throughout the school year is slow and relaxed enough for college-bound students to coast through quite easily. Although both socializing and sports activities are present in the college environment, they are not the main focus. The academic arena must become the main focus in order for students to be successful. Much more material is presented, at a higher level and faster pace than it was in the high school classroom. A single mathematics exam in college may cover the same amount of material as a semester or final exam in high school. In addition, all students are often required to take a comprehensive final exam, and many high school students have never been required to study for a comprehensive final exam. As a result they have no idea how to study the mathematics in which they are enrolled. Even students who took AP Calculus were often shocked at the results of their first college calculus exam (Ferrini-Mundy & Gaudard, 1992).

PPP at Texas A&M University

Some variables that were not examined in the prior chapters are important in determining student success in college mathematics and for retention in STEM majors. Plans for the future are to include surveys about study habits and student beliefs about mathematics knowledge and to analyze the responses. Some ideas being considered by Texas A&M Department of Mathematics to address additional issues involved in success in Engineering Calculus I include: 1) a fact sheet for students at New Student Conferences that will provide information about what is necessary for success in college mathematics and what resources are available to assist them, 2) periodic emails to students in the summer PPP to encourage them to continue being engaged throughout the 6-week program and provide them hints about studying mathematics, 3) a website with information about studying for success in mathematics, and 4) periodic emails to classes of students reminding them of actions they should be taking regularly (e.g., a checklist) to ensure success in college mathematics. Many instructors employ a number of strategies to encourage students, but expanding them to department-wide and course-specific strategies may help more students become successful.

Beginning in summer 2012, the PPP will be expanded to include students who score below 16 on the MPE. Although their probability of success is lower, there are students in that range who have strong motivation and determination to be successful in calculus. By allowing them to participate in the program, more students will have access, and the designers of the program can study parameters necessary to help them become successful. In addition a Just-In-Time (JIT) class will be offered to students to take along with Engineering Calculus I. The JIT class is designed to strengthen algebra skills necessary at the particular point in time each week for what is needed in the calculus course. The JIT class will be offered to all students in the calculus classes, not only those who have been identified at highest risk. The class will benefit all students who are struggling with adapting to the college academic environment in mathematics, even if they entered with strong mathematical skills.

Contribution to the Field

The research involved in the three articles in Chapters II, III, and IV contribute to the field of mathematics education in several areas. The meta-synthesis and meta-analysis complement the work done previously to evaluate the results of calculus reform and other measures designed to increase calculus understanding and student success, particularly as a result of National Science Foundation Grants (Ganter, 2001). Knowing what has worked well for precalculus and calculus students in other universities is a useful tool in designing an effective program in one's own university. In fact, that knowledge provides a stepping stone for the PPP at Texas A&M University. Lessons from the meta-synthesis will inform the decision to design a more comprehensive program than just online drill and practice. The personal contact with synchronous online tutoring in addition to an assessment of specific topics students needed to remediate will make the program more appealing and likely more successful.

Gathering the data, analyzing it, and presenting the results of the PPP contributed to knowledge about a particular intervention that has been successful in improving student precalculus skills before they take Engineering Calculus I. Students who participated in the PPP, followed through to completion, and retook the MPE were very successful in raising their scores. However, results in Engineering Calculus I were not as promising as anticipated. The difference between mean course grades of students who participated in the PPP before Engineering Calculus I and those who took Precalculus first was not statistically significantly different. However, the grades were lower for the PPP group. Some interesting results emerged from the study of the grades of the students, indicating that some other factors were at work. It seems likely that the academic demands of college in the first semester has an impact on grades. More support is needed for students besides remediation of precalculus skills. This series of studies informs the field about what occurred in this instance and provides ideas for thought in designing support programs and in furthering research for increasing college calculus success.

Recommendations for Further Research

Further research needs to be done focusing on the knowledge needed for college calculus remedial students. A number of different interventions have been fairly successful, but the technology available to universities and students is continually becoming more sophisticated. In order to find out what strategies and program components work best, researchers need to use qualitative methods to conduct content analysis of survey responses from faculty and students and analyze student work to understand more about the thinking processes and mathematical misconceptions students hold. Many studies in the last ten years have used those approaches. But that is not sufficient. Without quantitative data, it is difficult to determine what strategies and program components are needed to maximize student success. Giving passing percentages and mean scores is also not sufficient to contribute to the field of knowledge about strategies for improving student success in precalculus and calculus. Without standard deviations, clear information about the design of the study, including numbers of students in each control and treatment group, it is difficult to determine the best course of action. Knowing what works for a small group of students in a specific situation may be helpful, but being able to employ meta-analytic thinking to research available is much more conducive to being able to design and implement a program that will do the very best job possible for students.

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APPENDIX A

STUDY ID	Hedges's G	SE	W	Ctrl N	Trmt N	N	Design	E*W	Sum W(group)	Group Means	Wgp*Mgp	Wgp*Mgp^2	(Wgp*Mgp)^2	Wtd Within GP SS
2	0.1194	0.16	39.93	80	80	160	1	4.7687	129.4412	0.1473	19.0611	2.8069	363.3268	0.0309
6	0.1597	0.11	89.51	158	208	366	1	14.292						0.0138
3	0.1689	0.26	14.59	104	17	121	2	2.464	121.2560	0.6657	80.7145	53.7279	6514.8316	3.5990
4	0.7837	0.23	18.65	68	28	96	2	14.616						0.2598
5	0.5380	0.14	48.25	100	100	200	2	25.959						0.7869
7	0.7349	0.20	25.90	52	59	111	2	19.033						0.1242
8	1.3445	0.27	13.87	34	34	68	2	18.644						6.3900
							SumEW(gp1)=	19.061						
									250.6972		99.7756	56.5348	6878.1584	
							SumEW(gp2)=	80.715						0.0447
														11.1599
							All computations per Lipsey & Wilson					QB=	29.0987	
mean=	0.3980											df=	1	
												p(QB)=	0.0000	
												QW=	11.2046	
												df=	5	
												p(QW)=	0.0475	
												Q=	40.3033	

APPENDIX B

STUDY ID	Hedges's G	SE	W	Ctrl N	Trmt N	N	Design	E*W	Sum W(group)	Group Means	Wgp*Mgp	Wgp *Mgp^2	(Wgp*Mgp)^2	Wtd Within GP SS
2	0.1194	0.16	39.93	80	80	160	1	4.7687	129.4412	0.1473	19.0611	2.8069	363.3268	0.0309
6	0.1597	0.11	89.51	158	208	366	1	14.292						0.0138
4	0.7837	0.23	18.65	68	28	96	2	14.616	106.6695	0.7336	78.2505	57.4029	6123.1366	7.5539
5	0.5380	0.14	48.25	100	100	200	2	25.959						7.3667
7	0.7349	0.20	25.90	52	59	111	2	19.033						8.9432
8	1.3445	0.27	13.87	34	34	68	2	18.644						19.8760
							SumEW(gp1)=	19.061						
									236.1108		97.3116	60.2097	6486.4634	
							SumEW(gp2)=	78.25						0.0447
														43.7388
							All computations per Lipsey & Wilson					QB=	32.7378	
mean=	0.4121											df=	1	
												p(QB)=	0.0000	
												QW=	43.7835	
												df=	4	
												p(QW)=	0.0000	
												Q=	76.5211	

APPENDIX C

TAMU :: Personalized Precalculus Program - 2e

1: Graphs and Functions

1.1: Characteristics of Functions

1.2: Evaluating Functions

1.3: Polynomial Functions

1.4: Rational Functions

1.5: Radical Functions

1.6: Piecewise-Defined Functions

1.7: One-to-One Functions and Inverses

1.8: Exponential Functions

1.9: Logarithmic Functions

1.10: Solving Equations Using Logarithms

1.11: Applications of Exponential Functions

1.12: Transformations of Functions

1.13: Operations on Functions

2: Factoring and Solving Equations and Inequalities

2.1: Factoring Common Factors

2.2: Factoring Quadratic Expressions

2.3: Factoring Quadratic Form

2.4: Factoring Sums and Differences of Cubes

2.5: Factoring by Grouping

4.7: Applications of Trigonometry

APPENDIX D

TAMU PPP Survey for Tutors (Summer 2011)

1. Program Evaluation

***1. Your Name**

2. The questions below relate to your opinions of the technologies used for the TAMU Personalized Precalculus Program. Please rate each question below as you feel best describes your opinions.

	Strong disagree	Disagree	Neither agree nor disagree	Agree	Strong agree
I feel the the Centra online conferencing software allowed my students to learn, and benefit from, my online tutoring sessions.	○	○	○	○	○
I feel my students furthered their mathematical understanding and algebraic skills by using the WebAssign PSP.	○	○	○	○	○
I feel Centra online conferencing software used for the online tutoring sessions enabled me to be just as effective as if I were leading a face-to-face tutoring session.	○	○	○	○	○
Students reported that they encountered no significant problems in taking the online chapter/practice quizzes while participating in the TAMU PPP.	○	○	○	○	○
My students reported the videos available in WebAssign helped them complete their PSP.	○	○	○	○	○
I feel the videos available in WebAssign helped my students complete their PSP.	○	○	○	○	○
I feel the questions within the PSP helped prepare my students for the MPE.	○	○	○	○	○
I feel students received enough practice while completing their PSP to adequately prepare them to be successful on the MPE.	○	○	○	○	○

3. The questions below concern the training, and support, you received for the tutoring sessions.

	Strong Disagree	Disagree	Neither Agree nor Disagree	Agree	Strong Agree
I was well trained to lead the Centra tutoring sessions.	○	○	○	○	○
I was well trained to work within the WebAssign PSP.	○	○	○	○	○
I received good support from Jenn Whitfield before starting my tutoring session.	○	○	○	○	○
I received good support from Jenn Whitfield during the summer session in which I tutored.	○	○	○	○	○
I felt prepared to work with students in the TAMU PPP.	○	○	○	○	○
Based on my experience this year, I would agree to work in the tutoring program next year.	○	○	○	○	○

TAMU PPP Survey for Tutors (Summer 2011)

4. What percentage of your students do you feel actively participated in the online tutoring sessions?

- ◯ 100%
- ◯ 90%-99%
- ◯ 80%-89%
- ◯ 70%-79%
- ◯ 60%-69%
- ◯ 50-59%
- ◯ Below 50%

5. What percentage of your students do you steadily worked on their WebAssign PSP?

- ◯ 100%
- ◯ 90%-99%
- ◯ 80%-89%
- ◯ 70%-79%
- ◯ 60%-69%
- ◯ 50-59%
- ◯ Below 50%

6. List the top three items within the PPP tutor training modules that benefited and prepared you the most.

7. List the three items you would like to see added to the PPP tutor training modules so future tutors would be better prepared.

8. List the top three strongest features of the program. These would be features that you feel should not be changed or modified for future summer programs.

TAMU PPP Survey for Tutors (Summer 2011)

9. List the top three weakest features of the program. These would be features that you feel should be changed/modified for future summer programs.

10. Here are my suggestions for improving the content (i.e. videos, questions, etc.) available in WebAssign PSP.

11. Use the space below to list any problems that students reported while taking the online chapter/practice quizzes within WebAssign.

12. Use the space below to share any comments or thoughts you have about our Personalized Precalculus Program that you have not shared in any of the questions above.

APPENDIX E

TAMU PPP - Summer 2011 Student Program Evaluation (Version 3)

***1. Lastname, Firstname**

***2. In which session of the PPP were you enrolled?**

***3. How many online tutoring sessions, on average, did you attend per week?**

- 3 per week
- 2 per week
- 1 per week
- 0 per week

Use the space below to share any comments you have about the online tutoring sessions.

***4. Did you complete the entire WebAssign PSP?**

- Yes
- No

Use the space below to comment on anything you'd like regarding your experience with the WebAssign PSP.

5. Please rate your level of agreement regarding the questions below. These questions concern the Personalized Precalculus Program (PPP).

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The summer PPP helped me improve my understanding of algebra, trigonometry, and other precalculus concepts.	○	○	○	○	○
The summer PPP helped me improve my ability to solve mathematical problems.	○	○	○	○	○
The summer PPP was NOT beneficial nor a good use of my time.	○	○	○	○	○
I highly recommend the summer PPP to other prospective TAMU students.	○	○	○	○	○
The summer PPP was well worth the $100 fee.	○	○	○	○	○

TAMU PPP - Summer 2011 Student Program Evaluation (Version 3)

6. Please rate your level of agreement regarding the questions below. These questions concern the tutor you were assigned in the program.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
My tutor thoroughly explained the precalculus concepts to me.	◯	◯	◯	◯	◯
My tutor was organized in presenting and reviewing the material.	◯	◯	◯	◯	◯
My tutor kept the online sessions interesting and interactive.	◯	◯	◯	◯	◯
I recommend my tutor be hired to teach in this program next year.	◯	◯	◯	◯	◯

List the TWO MOST HELPFUL things and ONE LEAST HELPFUL thing your tutor did in the online sessions.

7. The summer PPP contained many different resources from which you could learn. Answer the questions below regarding your views on these resources.

	List of Resources
Which resource did you find the MOST helpful?	
Which resource did you find to SECOND MOST helpful?	
Which resource did you find to be the LEAST helpful?	
Which resource did you find to be the SECOND LEAST helpful?	

Please explain why you think these resources were most and least helpful.

8. Use the box below to offer your suggestions for improving this program.