DISSERTATION

A MIXED METHODS EXPLANATORY STUDY OF THE FAILURE/DROP RATE FOR FRESHMAN STEM CALCULUS STUDENTS.

Submitted by

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ABSTRACT

A MIXED METHODS EXPLANATORY STUDY OF THE FAILURE/DROP RATE FOR FRESHMAN STEM CALCULUS STUDENTS.

In a national context of high failure rates in freshman calculus courses, the purpose of this study was to understand who is struggling, and why. High failure rates are especially alarming given a local environment where students have access to a variety of academic, and personal, assistance. The sample consists of students at Colorado State University (CSU) who attended a course in freshman calculus from Fall 2007 to Fall 2012. An explanatory sequential mixed methods approach was used in this study.

Using data from CSU's Registrar's Office and Mathematics department, descriptive statistics highlighted several student attributes worth pursuing. Fall and spring cohorts have a different make up and different outcomes. Hence this study concentrated on the fall cohort, which comprises mainly of freshmen. The combination of attributes that produced the strongest prediction of student's final result in calculus were Colorado Commission on Higher Education index scores, CSU Mathematics department placement test scores, and calculus repeat status (R^2=.30, n=1325). For Fall 2012, these attributes were combined with student motivation and student strategies constructs, measured using the MSLQ instrument. The combination giving the strongest prediction of student's first mid-term examination results (R^2=.34, n=124) included CSU Mathematics department placement test scores, along with MSLQ constructs test anxiety, and self-efficacy for learning and performance. However, using logistic regression only 38.7% of the students who failed were correctly predicted to fail.

Former students of CSU's calculus course aimed at freshmen STEM students were interviewed or surveyed, in an attempt to probe how students experience this course. Several common elements emerged. Students were dedicating vast amounts of time to this course. There was a common belief this course could be passed if the student worked hard enough. The difference between those who succeeded and those who did not appeared to relate to how this study time was spent. Those who floundered often struggled to locate appropriate help, although they were quite aware they needed assistance. Many of those interviewed also avoided working with other students. Reasons cited ranged from claims of being individual learners, to frustration at finding a group who had the same study goals. Some non-traditional students were also alienated by the prospect of working with 'teenagers'.

Two other results from the analysis of student interviews suggested reanalyzing the quantitative data and including student's prior history with mathematics, as well as if the student was non-traditional. The combination of attributes that gave the strongest relationship (R^2=.40, n=101) were CSU Mathematics department placement test results, combined with MSLQ constructs test anxiety, self-efficacy for learning and performance, organization, as well as the student's own appraisal of the quality of mathematics teaching they received in high school. However, the ability to accurately predict if a student will fail was minimal.

Focusing on students who do fail, three groups of students of interest were isolated: those who have yet to declare their major, 'non-traditional' students, particularly those enrolled in the eight a.m. class, and, curiously, those students who choose to enroll in the ten a.m. class.

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CHAPTER I: INTRODUCTION

Overview

The number of students entering and completing science, technology, engineering, and mathematics (STEM) related subjects in the U.S. have received increased attention by education researchers. Part of the reason for this increased focus is the high failure/drop rate in these courses (Seymour & Hewitt, 1997). Students' success in these areas is seen as the key for the U.S. to remain strong in the global markets (Chen, 2009). However, many students are unable to succeed.

The calculus requirement of STEM courses is often perceived as a 'filter' rather than a 'pump' (Steen, 1988). High failure rates in calculus classes aimed at freshman engineering and science students are not new. Pilgrim (2010) has given an overview of the issues that have been identified and persisted nationally since 1894, focusing particularly on the calculus reform movement from the 1980's. Analysis of data for post calculus reform movement students has just been completed. The national 'DFW' rate is reported as twenty eight percent (Bressoud, Carlson, Mesa, and Rasmussen, 2012). This rate varies across the US.

Data analyses that relate to student retention in science and technology from the Organization for Economic Co-operation and Development (Hemmo, 2008) and the National Center for Educational Statistics (Chen, 2009) indicate the rates at which students leave a post-secondary institution before completing their studies is still quite high. Seymour and Hewitt (1997) thoroughly analyzed why students, who had course entrance scores indicating they should be more than capable of completing their chosen STEM course, dropped or switched from STEM majors in significant numbers. In many cases, students were initially undecided about which course to pursue (Firmin & MacKillop, 2008), but both Seymour and Hewitt (1997) and

Ulriksen, Madsen, Moller, and Henriette (2010) have indicated that students who stayed and those who dropped STEM majors have much in common.

There have been many attempts to remedy the high failure rate. Each intervention was aimed to address a specific issue seen to be key to student success. The more recent attempts include one study designed to improve student motivation to persist with the calculus course using anecdotes of students who had managed to improve their grades (Keynes & Olsen, 2008). Another slowed the rate the material was delivered to students specifically identified as needing an intervention (James, Montelle, & Williams, 2007). Both of these were determined to be qualified failures. Another attempt to adjust the pace of material to a targeted group did see an improvement in student outcomes, perhaps by incorporating oral assessments, as well as maintaining the focus of the students by keeping up course contact hours (Nelson, 2011). Both the interventions given to a targeted group relied upon placement tests to identify those students who would need an intervention. What the placement tests tested may also be the difference between these two interventions. Supplemental Instruction claims high success rates where used (Hizer, 2010; Peterfreund, Rath, Xenos, & Bayliss, 2008), and does not require a placement test to be implemented. So perhaps student attributes are the key.

Conditions at Colorado State University (CSU) appear to mirror those nationally. According to Pilgrim (2010), forty percent of those who took the course tailored to STEM majors (Calculus for Physical Scientists course I, MATH 160) needed to repeat it. Reinholz (2009) investigated a way for improving students' algebra skills that were identified as being at risk and found no statistically significant improvement in the outcomes for these students. Reinholz (2009) hypothesized that the study time taken to repair a weak background takes away from the time available for working on the new material presented in class.

Pilgrim (2010) analyzed an experiment designed to change student attitudes towards mathematics, targeting those who were struggling with MATH 160. An intervention course was made available to students who failed the first mid-term examination and then volunteered to take the experimental course. The transfer rate back to MATH 160 was too low (14 students out of the 94 who completed the intervention course) to determine if this course had an effect on their ability to subsequently succeed in MATH 160. Most of the students who were in the experimental course changed majors or institutions instead of retaking the course (Pilgrim, 2010).

Reinholz (2009) identified poor study skills as a potential factor (Reinholz, 2009) in the low success rate for the course. Therefore this researcher ran a pilot study of the shortened two-factor Study Process Questionnaire (Biggs, Kember, & Leung, 2001) on the Fall 2011 MATH 160 students to determine if the students' study approach could be measured against their performance in their first mid-term examination. One smaller than typical, but statistically significant result was found (r = -0.12 for surface strategy, see Table C6, Appendix C, and for a description of the pilot study subscales see Table C1 & C2, Appendix C). Furthermore, an investigation into the facilities available to students at CSU revealed there are numerous options available to aid students struggling in either study or life skills. After completing the pilot study, it seemed necessary to better understand the students who struggled, therefore the purpose of this study was to dig into past data to determine if there were common traits that can be identified, as well as find what can be learnt from students who have attempted the course.

Research Problem

Students still continue to fail Math 160 at a high rate. The research problem was to investigate the different student attribute variables that predict, or seem to affect, grades for students taking a freshmen course in calculus.

An explanatory sequential mixed methods design was used, and involved collecting quantitative data first and then explaining the quantitative results from insights gained in the qualitative analysis. In the initial quantitative part of the study, historical student data from Math 160 students at CSU were analyzed to identify groups of students who struggle with this course. Two surveys were also run on the Fall 2012 cohort as the literature suggested motivation and study strategies were additional variables to consider. For the qualitative part, past students of Math 160 were invited to relate their experiences in taking this course. Analysis of this data was used to confirm any influences of the variables identified in the quantitative part, as well as pick out other possible attributes that seem to influence success in Math 160. Finally, the Fall 2012 data were used to analyze different combinations affect on the ability to predict failure in this course.

Research Questions

The literature indicates, when prior ability is taken into account, there is little statistical difference between students who succeed in STEM courses and those who fail. These specific research questions are directed to find any sub-group, or subset, of traits that might be used to identify students who are at risk of failing, or dropping, a freshman calculus course for STEM majors. This information could then be used to target specific interventions to specific students.

Research question one (descriptive)

Are there any common traits exhibited by students who fail, or withdraw from the MATH 160 course?

Research question two (quantitative)

Are there combinations of variables that can predict if a student will succeed, or fail, in MATH 160? For example: Prior experience with calculus, or high school average grade point average.

Research question three (quantitative)

What kind of association (if any) is there between students persisting with the MATH 160 course and the predictor variables identified previously combined with the student's results from their first mid-term examination in MATH 160? For example: Is there an association between a student withdrawing from MATH 160 if they failed the first MATH 160 mid-term examination, had a low high school grade point average, or remaining in MATH 160 even though they failed the first MATH 160 mid-term examination but their predictor variables indicate they should do well.

Research question four (qualitative)

How do the students perceive their experiences of MATH 160?

Research question five (mixed methods)

What results emerge from comparing the quantitative data predicting a student's success, or failure, in MATH 160 with the qualitative analysis of the student interviews.

Definition of Terms

At-risk

Students who are likely to fail or drop out of MATH 160 will be referred to as ‘at-risk’ students.

American College Testing (ACT) Score

A test used to determine a student’s readiness for college developed and administered by a non-profit organization (ACT, 2012a). Areas tested are English, mathematics, reading and science. Writing is also an option (ACT, 2012a). A composite score is created using the results from the English, mathematics, reading and science tests and is the average of the four test scores (rounded to the whole number) (ACT, 2012b).

Collaborative Learning

Collaborative learning is characterized by the utilization of small groups whereby each member of the group assumes responsibility for their own learning of new material, as well as responsibility for each member of the team understanding the material. The students interact with each other and with the instructor (Cooper, 1990).

Colorado Commission on Higher Education Index Score

The Colorado Commission on Higher Education (CCHE) index score “is calculated using a combination of a student's high school GPA, or high score rank percentage combined with ACT or SAT score” (Colorado Commission on Higher Education, 2012a). The entrance requirement for Colorado State University is a score of 101 or higher (Colorado Commission on Higher Education, 2012b).

Concepts for Calculus (MATH 180)

The 'Concepts for Calculus' course (MATH 180) was an experimental course developed as an intervention program and offered to students who earned a 'D' or 'F' on the first mid-term examination in the MATH 160 Fall semesters of 2009 and 2010 and Spring Semester 2010. Instead of finishing MATH 160 in that semester, these students completed the intervention course, and were then expected to re-enroll in MATH 160 the following semester. MATH 160 enrolment details were removed from the Registrar's Office for these students and replaced with MATH 180 enrolment details.

The experimental course had two components: an online, and classroom. The Preparation for Calculus instructional software (referred to as 'ALEKS'), by the Assessment and LEarning in Knowledge Spaces (ALEKS) Corporation, is a software package designed to identify students' weaknesses in their mathematical background (pre-test), and guide the student through a set of learning modules and exercises designed to improve the student's ability to succeed in that task. This is followed by a post-test on each topic. The ALEKS component comprised ten percent of the student's overall grade.

The classroom component used group activities as well as written assignments to expand the student's view of mathematics. The aim was to deepen students' understanding of the concepts needed for the MATH 160 course. (Pilgrim, 2010).

Failure in MATH 160

Failure in MATH 160 is defined as a grade of 'F'. This differs from the definition used by Pilgrim (2010). A student with a grade of 'F' may not proceed to the next course in the calculus sequence, whereas a student with a grade of 'D', or higher can move on (Colorado State University, 2012g). However, each major may have different requirements. For example, a student enrolled in Mechanical Engineering will need to achieve a 'C' or higher in MATH 160 (Colorado State University, 2012e), whereas a student enrolled in an undeclared option and who is trying to transfer into engineering will need to achieve a 'B' or higher grade (Colorado State University, 2012h).

High School Sizes

A high school will be considered to be small if less than 400 students are enrolled (Small schools project, 2000), and large if more than 2,000 students are enrolled (High-Schools.com, 2012). A school is considered medium-sized if the number of students falls within these two ranges.

Motivated Strategies for Learning Questionnaire

The Motivated Strategies for Learning Questionnaire (MSLQ) is an 81-item instrument developed by Pintrich, Smith, Garcia, and McKeachie (1991a) to measure a college student's motivation and use of different learning strategies. The instrument uses fifteen subscales that have been grouped into two categories 'motivation', and 'learning strategies'.

Paced Algebra to Calculus electronically (PACe)

This is an online, self-paced, pre-calculus instruction program run by the Mathematics Department of Colorado State University. Certain topics offered by the PACe Center are required to be completed before the student can enroll in any of the calculus sequence of courses. This includes courses on algebra, trigonometry and logarithmic and exponential functions (Colorado State University, 2012a).

Persistence

A student will be considered persistent if they remained in their initial chosen degree program, including the students who failed courses along the way.

Reform Calculus Movement

In a reaction to the high failure rates documented in the 1980's, the National Science Foundation sponsored attempts to reform the teaching of calculus. The aim was to move away from students passively receiving knowledge through lectures, to students actively constructing their own understanding of calculus. The movement that ensued did not focus on a common method for teaching calculus but rather worked towards different ways of increasing student understanding of the concepts for calculus. The techniques involved (but were not limited to) student centered learning techniques, including cooperative learning strategies, aided by available technology. The concepts for calculus were to be given through multiple representations: verbal, numerical, algebraic, and graphical. The student understanding was to be reinforced, and demonstrated, through written and oral presentations. (Pilgrim, 2010.)

Repeat/Delete option

At CSU, a student who fails a course has the one-time option to 'repeat/delete' their results. If the student chooses this option, the result of the failed course is removed once the results of the retaken course are available. (Colorado State University, 2012b).

Retention Rate

The National Center for Education Statistics (2011b), defines retention rate as:

> "A measure of the rate at which students persist in their educational program at an institution, expressed as a percentage. For four-year institutions, this is the percentage of first-time bachelors (or equivalent) degree-seeking undergraduates from the previous fall who are again enrolled in the current fall. For all other institutions this is the percentage of first-time degree/certificate-seeking students from the previous fall who either re-enrolled or successfully completed their program by the current fall." (para. 1).

SAT test score

The SAT is another test used to determine a student's readiness for college developed and administered by a different non-profit organization, College Board and is an alternative to the ACT test. (SAT, 2012).

Self Regulated Learner

Zimmerman (1986) defined a self-regulated learner as:

> "Metacognitively, self-regulated learners are persons who plan, organize, self-instruct, self-monitor, and self-evaluate at various stages during the learning process. Motivationally, self-regulated learners perceive themselves as competent, self-efficacious, and autonomous. Behaviorally, self-regulated learners select, structure, and create environments that optimize learning. According to this view, effective learners become aware of functional relationships between their patterns of thought and action (often termed strategies) and social and environmental outcomes." (p. 308)

Shortened (Revised 2 factor) Study Process Questionnaire (R-SPQ-2F)

This instrument was developed in 1987 by Biggs (1987) and redeveloped in 2001 (Biggs, Kember, & Leung, 2001). This instrument was based upon the 'Student Approaches to Learning' (SAL) theory developed by Marton and Säljö (1976a, 1976b). The instrument was designed to measure the approach a student takes to studying.

The study approach was seen to be a composite of both 'motive' and 'strategy'. Students exhibit varying levels of these constructs depending upon their background, ability, educational experiences, aims, as well as things beyond their control such as the expectations of the institution that they are studying at, and the structure of the courses they have chosen (Biggs, 1987). The R-SPQ-2P version used in this study is the revised two-factor version from 2001.

STEM

STEM is used as an acronym for Science, Technology, Engineering, and Mathematics.

Study Skills

For a postsecondary environment, the study skills a student would be expected to use in some form are:

- The ability to employ study techniques to understand the material they are expected to cover.
- Being able to demonstrate their understanding in either written or verbal form.
- Process all feedback to correct any misunderstandings.
- Implementing a study plan thus setting aside appropriate amount of time to complete the tasks required to understand and demonstrate understanding of the course.

(Martin, Arendale, & Associates., 1992; Pintrich et al. 1991a)

Study Strategy.

The instruments reviewed for this study define study strategy within their own manuals. As the term ‘deep’ and ‘surface’ learning strategies are used by several articles in the literature review, a definition of these terms is included here:

Deep strategy.

The student actively works to understand the material through actively exploring new material and making connections with previous knowledge (Biggs, 1987)

Surface strategy.

The student is less engaged by the material and seeks to do the least amount of work possible to pass. This is often associated with using rote learning alone, or just being able to produce an answer to a question by “pattern matching” a previously seen problem (Biggs, 1987).

Withdrawal

Withdrawal from a course refers to the formal process a student undertakes to exit from a course. In this case a code of ‘W’ is recorded on their Academic Transcript. A student may also choose to cease attending lectures or doing any assessment. In such cases the student will receive a final grade other than ‘W’.

Limitations and Assumptions.

For this study I have assumed the following:

- The students coming into Math 160 have equal access to facilities that adequately prepared them for the course they enrolled in. That is, they competed the required prerequisites and they did not receive an intervention course at high school. The quantitative part of this dissertation looked to see if the reasons why students did not achieve a passing grade was based upon their own individual preparation, motivation, and study skills. The qualitative part attempted to identify if there were other reasons.
- The data supplied to me were accurate.
- The students I interviewed were open and willing to tell the truth.
- If a student decides they require help in a course, CSU has several different options available to them from tutoring services run by the Mathematics Department, recitation classes run though the School of Engineering, as well as tutoring and online courses available though the Institute for Learning and Teaching. Students also have access to outside tutoring services, as well as book and online resources. I have no control over any of these services offered to the student.
- Included in this study will be students other than freshman.

Delimitations

The main focus of this dissertation was on freshman students enrolled in the MATH 160 course. This study has the following delimitations:

There are other freshman STEM calculus courses offered at CSU. Another course caters to Biological Science students, and during the fall semester 2012 students wishing to enroll in MATH 160 also had the option to take a five-credit version of the course. Only MATH 160 students were included in this study.

There was a limit to the online student record data available. Records from Fall 2007 onwards were stable, so Fall 2007 was used as the lower bound. Interventions were also tried in different semesters, and so, where necessary, analysis was restricted to semesters where no interventions were used.

The students invited to attend interviews were selected from the Fall 2009, Fall 2010, and Fall 2011 cohorts to improve the likelihood of interviewing students who might remember their experiences of taking MATH 160, and had not yet finished their degree, and so were still in Fort Collins, as well as being freshmen students in those selected semesters.

Population

For phase one, data for all students enrolled in MATH 160 at Colorado State University from Fall 2007 to Fall 2011 (n = 3039) were used.

For the quantitative part of phase two, students enrolled in six sections of MATH 160 course at Colorado State University in Fall 2012 (n = 248) were analyzed.

For the qualitative part of phase two, students who completed MATH 160 in Fall 2009, 2010 or 2011 were invited to either attend an interview, or complete a survey. Thirteen students were interviewed and twenty-seven students chose, instead, to complete a survey.

For phase three, the data for students enrolled from Fall 2007 to Fall 2011 (n = 3039), as well as six sections of MATH 160 course at Colorado State University in Fall 2012 (n = 248) were reanalyzed.

Context

Calculus for Physical Sciences I (MATH 160) is a one-semester calculus course offered by Colorado State University that is the first in a three part series of calculus courses aimed at students majoring in Engineering, Mathematics, Computer Science, Chemistry, or Physics. It is worth four credits. The course, as presented on the main campus at CSU (in Fort Collins), has features from both traditional calculus courses and from calculus reform movements, emphasizing both understanding and ability to communicate concepts. Students who take MATH 160, but not on the CSU Fort Collins campus, were excluded from this analysis.

In fall and in spring, the Fort Collins campus version of MATH 160 is offered as four 50-minute lectures per week. Several sections are offered each semester (except during the summer, where only one section is available in an accelerated course). A member of the CSU Math faculty coordinates all the sections. The sections range in size from small (about thirty five students) to large (over sixty students).

There are three one and three quarter hour examinations during the semester (each worth 100 points) held in the evening for the whole cohort, and a two hour final examination at the end of the semester (worth 200 points) again held at a common time for the whole cohort. The course coordinator writes all the examinations. The course instructors, homework graders, and course coordinator, using a common grading key, grade all the completed examinations as a group effort. During the period covered by this study, a total of 200 points of the course points were allocated to assignments completed by the students throughout the semester, such as twelve to sixteen written homework exercises, twice weekly on-line exercises, and six in-depth investigations.

Nearly all of the instructors for MATH 160 are Graduate Teaching Assistants (GTA's). Other instructors are visiting Post-Doctoral fellows, employed instructors, or the course coordinator. The GTA's and Post-Doctoral fellows who teach this course change each semester. If a GTA has taught MATH 160 more than once, the time of day they teach the course may change.

New mathematics GTA's receive a day and a half training on presenting to a class, which is followed up by senior Mathematics Graduate students attending two class sessions: the first to give feedback to the GTA and record recommendations; the second to ensure the recommendations were followed up by the GTA. This is not done for Post-Doctoral fellows, employed instructors, or faculty who teach MATH 160. During semester, the course coordinator keeps in weekly contact with the GTA's who are teaching MATH 160 to assist with any issues the GTA's may have, and keep the sections synchronized.

Researcher's Perspective

The purpose in doing this thesis was to better understand some of the common factors contributing to a high failure rate in 'Calculus for Physical Scientists I'. I have taught this class for five semesters at Colorado State University, and have been impressed by the variety of impediments to success the students seem to face. I thought to improve the outcomes of those students who struggle, it was worthwhile identifying if different groupings of student attributes could be found, so that different interventions might be applied to each group as appropriate. I believed a mixed methods approach would give me more satisfying answers than attempting to do this with only quantitative methods or with only qualitative methods. The quantitative side gave me the numbers I needed to support conclusions I made about students who are likely to fail or drop, however, listening to what the students had to say enriched the interpretation of the findings. While this may be seen as pragmatic, it could also be seen as the scientific method at work, whereby the students are truly observed before a conclusion is made about either the student's original behaviour, or any behaviour they may exhibit after beginning a semester of post-secondary study in mathematics.

CHAPTER II: A REVIEW OF THE LITERATURE

A high failure rate in a calculus class aimed at freshman engineering and science students is not new. Pilgrim (2010) has given an overview of the issues that have been identified and persisted nationally since 1894, focusing particularly on the calculus reform movement from the 1980s. Analysis of data for post calculus reform movement students has just been completed. The national 'DFW' rate is reported as twenty eight percent (Bressoud, Carlson, Mesa, and Rasmussen, 2012). This rate varies across the US. Wilson (1997) gives anecdotal evidence of institutions where failure rates have dramatically decreased (from 30% to 11% at the University of Michigan) and reform has been confirmed a success (Stanford University, in Wilson, 1997). However, he notes that the calculus reform movement had strong critics, who claim that the course is not rigorous enough and produces students who are unable to solve mathematical problems. In Silverberg's study (1999), the benefits of the reform movement approach were not detected in the students who took the reform movement courses until the third course in the calculus sequence, and further, the new approach took three semesters to fully develop. So the effects of the reform movement may not be detected immediately.

What data analyses are available relates to student retention in science and technology from the Organization for Economic Co-operation and Development (Hemmo, 2008) and National Center for Educational Statistics (Chen, 2009). This indicates the rates at which students leave a postsecondary institution before completing their studies is still quite high.

To better understand the implications and current standing of retaining engineering and science students and improving their outcomes in a freshman calculus course, this literature review will cover student characteristics, previous attempts to improve pass rates, and studies focusing on a student's willingness to persist.

Before Course Enrollment

Failure rates in calculus

Failure rates in freshman calculus courses are high (National Science Foundation, 2000). At Colorado State University (CSU) Pilgrim (2010) cites a forty percent failure rate, and forty percent nationally (University of Colorado at Boulder, 2011b) however it is unclear if the definitions of failure are the same.

Attempts to reduce the failure rate both locally and nationally have had varying degrees of success (Wilson, 1997). However, it may be the case the student demographic has changed and the new cohorts have different issues (Dumais, 2009; Meriac, Woehr, & Banister, 2010). This possibility was not examined here. What was analyzed in this study was the ability to predict which students needed an intervention by considering what students themselves see as the impediments to their success.

Impact of failure rate

Student failure has impacts on several levels, including both the cost to students financially, as well as a cost of extra time to complete the degree of choice. There will also be a cost to those who may be sponsoring the student (Firmin & MacKillop, 2008; Seymour & Hewitt, 1997, Chapter 1; Van Bragt, Bakx, Bergen, & Croon 2011). At CSU for the Fall 2010 semester, approximately seven percent of those enrolled were repeating the course; and for Spring 2011 approximately 17 percent of those enrolled were repeating the course (Colorado State University Registrar, 2011). The Mathematics Department at CSU determines the number of sections it will hold based on need, funding and availability of instructors (H. Freeman, personal communication, 5th May, 2011). However, the above numbers account for one small section in the fall semester and two small sections in the spring semester.

Analysis of reasons for this failure rate

Many reasons have been put forward as to why students fail, or change courses or dropout. Some students may enroll in a course without adequately looking into what they were signing up for (Firmin & MacKillop, 2008), or they enroll in a course without really understanding where their own interests lie (Firmin & MacKillop, 2008; Leuwerke, Robbins, Sawyer, & Hovland, 2004; Van Bragt et al. 2011). Some students have personal inhibitions to committing to any long-term goal (Van Bragt et al., 2011). Students who are under prepared for the course will also be at risk of dropping out or switching courses (Kreysa, 2006). From a large study (n = 54,336) based on SAT data, it was found students who persist with their courses have a high belief in their own ability to do science-based courses, as well as a strong preparation in mathematics and science subjects (Swan & Barbuti, 2010). Conversely, those who switch out of STEM courses had a lower self-efficacy for mathematics and science scores and were less prepared. (Swan & Barbuti, 2010). Whereas Ulriksen et al. 2010 reinforced Seymour and Hewitt's (1997, Chapter 7) conclusion that negative learning experiences endured during the course had the most effect on student retention. In a work environment Rafferty and Griffith (2006) reported a link between lack of "job satisfaction" with the willingness to leave a company (Rafferty & Griffith, 2006). As negative learning experiences also affected those who stayed, then perhaps a lack of job satisfaction was more important to those who leave where, as Seymour (2002) suggests, students who remained enrolled in their courses were more intrinsically interested in the courses.

Disconnect between high school and post secondary level environments

For most high schools, teaching students is the core business. Students may have a hard time adjusting from that environment to enrolling in a research institution, where both research and teaching are core business. In particular, research is very important in maintaining a research institution's standings (For example: CSU, 2005; Oxford University 1998; UWA 2008).

The classes in a postsecondary institution are often larger with less access to faculty (Seymour & Hewitt, 1997, pp. 125 - 127). Research institutions hiring faculty staff often require these people have some teaching experience but there is no requirement for these people to be trained in teaching (Hemmo, 2008). People applying for positions at the Mathematics Department at Colorado State University are required to have a Ph.D. (that is, qualifications in research) and to have demonstrated effective teaching skills, but there is no explicit requirement for an applicant to have teaching qualifications (CSU, 2011a). Certainly teaching is not the only focus of faculty.

Furthermore, students move from an environment where they have a large number of organized contact hours, with teachers who regularly reminded them of due assignments, with study time monitored by their parents, to an environment where they are no longer at home, have fewer contact hours, and are responsible for organizing their own time (van der Meer et al., 2010). Van der Meer et al. (2010) in their literature review noted this issue is widespread across the globe. Van der Meer et al. (2010) developed a "Readiness and Expectations" questionnaire to determine how prepared students enrolling at both University of Otago (New Zealand) and University of Groningen (The Netherlands) believed they were before starting at these institutions. These students believed they were adequately prepared to study at university and expected the workload would be similar to high school (n = 440, University of Otago and n = 1465 University of Groningen) (van der Meer et al., 2010). Qualitative data analysis of the interviews indicated students understood the management of their postsecondary studies would be different to high school, however some students did not know how to adjust to the different amount of work expected. However, some students had a late realization that they were now responsible for meeting assignment deadlines and making their own study schedule, not the university, or their instructors (van der Meer et al. 2010).

A study by Hong et al. (2009) sought the views of high school teachers, and tertiary lecturing staff about student transition from high school to post-secondary calculus. Teachers believed that students, both in high school and in post-secondary institutions, were aiming to pass rather than attempting to gain a high level of academic performance. Certainly one of my students greeted a “C” he earned in one of his mid-term mathematics examinations with the relieved exclamation: “C’s gets degrees”.

Mathematics is often a service course for other majors. It is possible students might lack intrinsic motivation to study mathematics if only a passing grade is required. This may lead to retaining surface learning strategies, which may have been quite successful in a high school environment, but may not be appropriate in a post-secondary setting (Kajander & Lovric, 2005; Seymour, 2002). In two other studies the expectations of instructors at high school and post-secondary levels were compared. Generally high school emphasized drill skill knowledge and post-secondary institutions emphasized critical thinking skills such as being able to explain why (Daempfle, 2003; Quinn, 2012).

Reasons for failure were identified and compared by instructors and students in New Zealand (Anthony, 2000). The instructors believed their students lacked background knowledge, had poor study skills, and gave insufficient effort outside of the classroom. The failing students blamed the tests. They expected to be able to pattern their test answers to the answers for the questions in their assignments. Further, they found the course demanded too much of their time (Anthony, 2000). A study of students at an east coast state university in the USA (n = 379) who dropped chemistry or mathematics found that these students were more likely to believe knowledge is fixed and not to be questioned, and they could not adjust (McDade, 1988). Having successfully used surface learning strategies for many years, a student may be resistant to change, or not know how to implement other strategies (Zimmerman, 2008).

Bernold (2007), looked specifically at engineering students using the Learning and Study Strategies Inventory (LASSI). He found fifty percent of the freshman engineers in the study at the University of Austin Texas, (*n* = 920) were not adequately prepared for their chosen course. The students lacked adequate skills in time management, ability to assess their own levels of understanding, as well as utilizing standard study aids (Bernold, 2007).

An informal online survey conducted on post-secondary students attending institutions in Mississippi (*n* = 254) identified the top seven study skill areas these student's believed they needed to improve. They were: different ways to study (92.9%); note taking (87.8%); time management (85%); examination technique (82.3%); listening skills (78.7%); reading comprehension (75.6%); and organization skills (74.8%) (Simmons, 2006). Van der Meer et al.'s (2010) qualitative data analysis also reinforces time management as an issue.

Seymour and Hewitt (1997) undertook an ethnographic study of students who left ("switched from") STEM related majors. The study included both students who switched from their STEM majors as well as those who stayed. Most students were individually interviewed (75%) and the rest were interviewed in small groups of three to four. A cross-section of four year postsecondary institutions were represented in the study. Table 2.1 has been adapted from one of their summary tables that high-lights the top ten reasons given by students as to why they switched out of STEM courses, and also includes the percentage of similar complaints from those who stayed in their majors. When asked to list what barriers they had to learning in post-secondary institutions ninety percent of students in Seymour and Hewitt's (1997) study who dropped, or switched, from their original course flagged poor teaching as a significant issue, and 74% of students who remained agreed. (See Table 2.1.) Anthony (2003), found similar results.

Table 2.1.
Top Ten Issues Contributing to Decisions to Switch for STEM Courses.

Issue	Percentage of switcher's with the concerns	Percentage of non-switcher's with same concerns
Poor teaching by science, mathematics, or engineering faculty.	90	74
Reasons for choice of science, mathematics, or engineering major prove inappropriate.	82	40
Inadequate advising or help with academic problems.	75	52
Lack of/loss of interest in science, mathematics or engineering: "turned off science".	60	36
Non-science, mathematics, or engineering majors offers better education/more interest.	58	32
Curriculum overload, fast pace overwhelming.	45	41
Science, mathematics, or engineering career options/rewards felt not worth the effort to get the degree.	43	20
Rejection of science, mathematics, or engineering careers and associated lifestyles.	43	21
Inadequate high school preparation in subjects/study skills.	40	38
Discouraged/ lost confidence due to low grades in early years.	34	12

Note. Adapted from Table 1.6 Chapter 1, Seymour and Hewitt, (1997), p. 33.

As students move into the realm of adult education, they are expected to become self-regulated learners. It is difficult for freshman to gauge what is required of them if in the past they have either found the material to be too easy, or they have suffered from experiences that have knocked their confidence (Lynch, 2006; Seymour & Hewitt, 1997). Most students manage to set for themselves effective study goals, and monitor how well they are attaining these (Lynch, 2010), but a group of students will need assistance in making this transition from high school to post-secondary education (Taylor & Mander, 2003).

Anecdotally, a number of MATH 160 students from the class I taught in fall 2010 who did fail the course had been “A” students at high school. They candidly admitted that they had not needed to work at mathematics in high school. Others who gained a “D” as their final grade said they had an uneven relationship with mathematics, sometimes gaining good grades, and other times not. Another group who had withdrawn from the course during the semester appeared to know they had to work hard to pass. These students perhaps did not have appropriate study techniques, or knew techniques but did not know how to apply them to mathematics (Zimmerman, 2008). Failing a mid-term examination was enough of a catalyst for them to withdraw. While instructors from other sections of the MATH 160 course talk of students who persisted, and failed, despite receiving strong advice to withdraw from the course.

What affects a student’s ability to effectively learn?

As students are individuals, there are numerous possible factors affecting each individual to a greater or lesser degree. The following associations have been analyzed and reported.

Attitudes and approaches to learning freshman mathematics.

Undergraduate student attitudes towards mathematics were compared with their study approach at a Mid-western university in the USA (Alkhateeb & Hammoudi, 2006). Two study approaches, deep and surface, as measured by a version of the Study Process Questionnaire (developed by Biggs, 1987) were compared to student attitudes as measured by the Mathematics

Attitude Scale (developed by Aiken, 1972). Alkhateeb and Hammoudi (2006) reported (n = 180), 31.7% of the variability in the deep approach construct could be explained by the student's attitudes towards mathematics. Similarly 10.4% of the variability in the surface approach construct could be explained by the students' attitudes towards mathematics.

Mathematical beliefs, self-regulation learning styles and achievement.

Crede, Roch and Kieszczynka (2010), performed a meta analysis on studies that either reported a correlation between students' class attendance and class grades, or class attendance and student grade point average, or any such correlation result that could be calculated from the data provided. From 69 of these studies, a strong correlation between students' class attendance and class grades was identified (n = 21,195, ρ = 0.44). Among 33 studies a strong correlation between student class attendance and student grade point average was found (n = 9,243, ρ = 0.41). This appeared to be true regardless of the talents of the teacher, but may relate to student beliefs about studying a subject and the amount of time they have invested in it.

A number of post secondary institutions run remedial mathematics courses as students entering these institutions come from a wide variety of backgrounds. Some students need to take the same remedial course more than once. Briley, Thompson and Iran-Nejad (2009), examined the outcomes of a group of post secondary remedial mathematics students at a Southeastern regional university. They investigated if the transition from an environment where a student's time use had been largely determined for them to an environment where they had more control over how they spent their time caused problems for those who took remedial courses. They also looked at whether a student's beliefs about mathematics might be involved in the student's ability to regulate their own time. Although the researchers interpret their results with caution, owing to the small sample used (n = 94), students who believed mathematics was useful, and who were able to use active learning strategies, were positively correlated with those who did well in these remedial courses (Briley, Thompson & Iran-Nejad, 2009). The ability to self-regulate did have a positive effect on a student's achievement in both mathematics and other courses the student was taking.

Zimmerman (2008) noted that students might know of better study methods than the ones they actually use but not know how to apply them, at least not in all of the subjects a student may be studying. For example, a student may apply study techniques associated with high achievement in a physical experimental science subject, but they may not know, or be interested in applying those techniques to a subject that does not have physical experiments such as mathematics. The student's ability to manage their own time depends upon how fast the student can adapt their organization skills to the change in environment (van der Meer et al., 2010), and what they adapt to depends upon their beliefs about the subject they are studying, in this case mathematics (Briley, 2008). A student's ability to adapt and succeed depends upon their prior experience of mathematics (Kajander & Lovric, 2005, Post, et al 2010). Certain learning experiences may either reduce the ability of a student to adapt, or set false expectations for the student about the nature of mathematics.

In the context of CSU.

A survey study of CSU sophomore students from 2011 is currently underway at CSU. In this survey, students were given the opportunity to respond to the prompt: "Please share what strategies have helped you in your sophomore year". Of the 357 responses given, nearly twenty percent identified survival of their freshman and subsequent years depended upon their ability to organize themselves (L.A. Varela, personal communication, 11th November, 2011). Reinholz

(2009) also hypothesized that students coming into the freshman Calculus courses at CSU lack an understanding of mathematics, are poorly prepared, and have poor study skills.

Once Classes begin: What has been tried?

Many different interventions and studies have been reported. Most are based upon the premise that a student's learning experiences affect their study behaviors ($\beta = 0.23$), which in turn affects their performance ($\beta = 0.36$) (Ning & Downing, 2010a). Others include motivation, beliefs and attitudes into their model (Kim & Keller, 2010).

More motivation.

Kim and Keller (2010) tried to improve both the student's motivation and beliefs about their ability to do calculus to improve student outcomes. This was a qualified failure. Throughout part of a semester, the students were given encouragement and anecdotes via email about other students who had successfully turned around their poor grades in calculus. The duration of the experiment was short (eight weeks) and Kim and Keller (2010) reasoned there may not have been enough time for an effect to take place. The method used to carry out the intervention may also have been at fault because long emails may have been deleted before being read (Kim & Keller, 2010).

More positive attitudes.

The results of an experiment designed to change students' attitudes towards mathematics, targeting those who were struggling with the freshman calculus (MATH 160) course at CSU, was analyzed by Pilgrim (2010). The instruments used to measure student beliefs and attitudes was based upon the Indiana Mathematical Beliefs' Scales (IMBS) by Kloosterman and Stage (1992) and the Mathematics Usefulness Scale by Fennema and Sherman (1976). Students' results from the first of three mid-term examinations given to CSU MATH 160 students (four weeks into semester) was identified to be a good predictor of the results the students were likely to have at the end of semester ($r = 0.70$, $p < 0.001$) (Reinholz, 2009).

A “Concepts for Calculus” course (MATH 180) was developed as an intervention program and offered to students who attained a “D” or “F” in the MATH 160 first mid-term examination. Instead of finishing MATH 160 in that semester, these students completed the intervention course, and were then expected to re-enroll in MATH 160 the following semester. The transfer rate back to the first-year calculus course was too low to determine if the intervention course had an effect. Instead, an appreciable number of the students who were in the experimental course changed majors or institutions (Pilgrim, 2010).

More challenge.

The University of Minnesota implemented a new calculus curriculum during the 1995–96 school year aiming to improve levels of achievement through improving attitude and interest in the course (Keynes & Olson 2008). The method of instruction was changed to reduce class time to two 50-minute sessions per week, introduce one 100-minute and one 50-minute workshops per week, and large-scale team projects, which required reports to be written to a professional standard. Keynes and Olson (2008) claimed the students in the new curriculum demonstrated a higher achievement and retention rate than those in the control group (old curriculum), indicating an increased level of engagement with the more challenging course material. Using more challenging material to engage students is part of Csikszentmihalyi’s flow theory. Schweinle, Meyer, and Turner (2006) summarized Csikszentmihalyi’s flow theory as a method to extend students’ skill set by giving the students tasks they would find challenging. This method has been demonstrated to work well on talented, high-achieving students who find the tasks intrinsically interesting. However, students who do not aim high can be discouraged by such challenges

(Schweinle, Meyer & Turner, (2006). If Hong et al. (2009) are correct, and many students at post-secondary level are merely aiming to pass, then methods of flow theory may be more discouraging than helpful if the tasks are not set at the right level. It should be noted that students at the University of Minnesota in Keynes and Olson's (2008) study were required to pass a placement test before enrolling in this course, therefore students who had poor preparation were not represented. The instructors may have been more engaged in teaching in this new environment as well.

More preparation.

Locally, Reinholz (2009) studied one way of strengthening students' mathematical background using the Preparation for Calculus instructional software (referred to as "ALEKS"), by the **A**ssessment and **Le**arning in **K**nowledge **S**paces (ALEKS) Corporation. This software is designed to test where there are weaknesses in a student's mathematical background (pre-test) and then guide the student through a set of learning modules and exercises designed to improve their ability to succeed in that task. An aim of Reinholz's (2009) study was to address any weakness the CSU students may have had in their mathematical background before their lack of background caused them to be overwhelmed by their chosen calculus course. This was followed by a post-test on each topic the student worked though. Both spring (n = 253) and fall (n = 439) cohorts of the Calculus for Physical Sciences course (MATH 160) during 2008 were given access to use the software in the four weeks before the first mid-term examination. Additional motivation to use the software was provided by including the post-test score as ten percent of their final grade. Eighty percent of the topics in ALEKS were required to be completed for the student to achieve the full ten percent offered. The population and sample for the experiment were all of those enrolled in Calculus for Physical Sciences I, however the group selected for analysis was not the whole cohort. The analysis was restricted to the data from just one of the sections. The rationale behind this decision was to reduce the impact of “teacher effect” (Reinholz, 2009), but choosing to use the data from just one instructor did reduce the data pool considerably. The sections from the MATH 160 course can vary from small (25 – 35) to large (60 – 120). The instructor chosen was the most experienced instructor available who taught one of the larger sections (Reinholz, 2009). Reinholz (2009) found no improvement in student outcomes and suggested time spent on ALEKS took away from time available to be spent on the rest of the course material: a conclusion supported by Seymour and Hewitt (1997, p. 89).

More measured approach.

An alternative approach is to deliver the course over a longer period of time, giving students longer to understand the material. The success of this approach appears to depend upon the implementation. At the University of Canterbury, NZ, students identified as having a weak background were given the option of doing the course over two semesters instead of one (James, Montelle, & Williams, 2007). An explicit assumption was that slower presentation of the same material would allow students time to repair a weak background and absorb the new concepts. The one-semester course was given for four hours per week, whereas the two-semester course was the same course but given for two hours per week. At the University of Canterbury, as is also true of many Australian universities, the standard first year course for mathematics, science and engineering majors would include both calculus and linear algebra. Half the classes in any one week would cover material from calculus and the other classes would cover linear algebra. The pass rate of the students who were given the material over a longer period of time did not improve. James, Montelle and Williams (2007) concluded a slower presentation did not make up for a lack of effort on the part of the student to repair weaknesses in their background: the original problem remained. Perhaps the reduction in student contact hours also translated to a reduction in the time the student spent on mathematics overall, as their study emphasis for that year shifted away from mathematics.

The University of Colorado at Boulder took a different approach by giving a slower presentation combined with a "Calculus Assessment Pre-Test" (University of Colorado at Boulder, 2011c). Before a student can enroll in any freshman calculus for engineering students course, they are required to take a pre-test. This pre-test was reported to be an excellent predictor of student success in the Calculus I for Engineers course (University of Colorado at Boulder, 2011a). Based upon the results of this test, students are encouraged to enroll in the Calculus I for Engineers (APPM 1350 one semester) or the Calculus with Algebra I and II (APPM 1340/1345 two semester) course. The two-semester version of the course covers the same material as the one-semester course (same as the New Zealand example); however, it also covers algebra and trigonometry (required background material), presenting any required concepts as they are needed for the calculus material. Both the one-semester and two-semester versions of the course meet for lectures three times a week, as well as one recitation session a week. The two-semester course also has voluntary oral assessment sessions held prior to each examination (University of Colorado at Boulder, 2011a). The students are required to register for these sessions ahead of time, and each group comprises of four to five students. In these sessions, learning assistants ask students to present answers to conceptual questions about the course material. Thus students are tested on their understanding of the course material, as well as their memorization of it (University of Colorado at Boulder, 2011f). The oral assessment approach has not yet been done with the one-semester version of their calculus course. Student persistence and success in subsequent calculus courses was used as a measure of success in this course (University of

Colorado at Boulder, 2011a), as well as the oral assessment treatment they were concurrently evaluating. It is claimed this combined treatment has reduced the course fail rate to under 22% (University of Colorado at Boulder, 2011e).

More instruction.

Supplemental instruction (SI) is an approach where classroom instruction is supplemented by other means. Small study groups of heterogeneous ability are formed, which are led by a “peer facilitator”. The peer facilitator is a former student of the course who did well. This peer facilitator is given training before the semester starts in leading a group to work towards every group member understanding the material covered in lectures. Not all students need additional support, so attendance to supplemental instruction study group sessions is encouraged but not mandatory. As attendance is voluntary, there is a reduced risk to each group that one of its members does not want to be there and therefore will not contribute to the success of all group members (Martin, Arendale, & Associates, 1991). Supplemental instruction is not conceived as a remedial intervention, which is why the group members should be heterogeneous in ability. Its implementation is aimed at courses that have high failure rates (Martin, Arendale, & Associates, 1991), as timely identification of at-risk students can not only be difficult but sometimes those who do well in entrance examinations still do not always do well in postsecondary courses. Indeed, the aim is to address a number of reasons students withdraw from a course: social isolation; difficulty in adjusting to new teaching styles; difficulty in integrating course material to what they already know; and difficulty in adjusting to the college setting (Martin, Arendale, & Associates, 1991).

Supplemental instruction is based upon students constructing their own knowledge through collaborative learning strategies as well as interaction with others (Martin, Arendale, &

Associates, 1991, p. 47). Instead of the course instructor acting as facilitator, the facilitator role is played by a student who has previously successfully completed the course. The use of peers as facilitators is deliberate. Each peer facilitator is responsible for a small number (12 – 15) of students per semester, whereas the instructor may be in charge of a large section (60 – 120). In this cooperative group environment, the peer facilitator acts as the "more capable peer". Using peer assisted learning and groups in this way brings the students together, allowing the possibility of reducing any individual student's sense of isolation, which is important in increasing student retention rate (Tinto & Cullen, 1973; Treisman, 1992).

The peer facilitators have control over what is covered in the study sessions. It is expected the peer facilitators will be role models, and so, present learning strategies that have worked for them, as well as, standard recommended strategies in note taking, test review, and resource management (Martin, Arendale, & Associates, 1991). The group study sessions of supplemental instruction are geared towards the attendees gaining a better understanding of the course, rather than reviewing the material in it, so group discussions on course work are also expected. Students' understanding is increased by having to explain their reasonings to others (Nelson, 2005), and a supportive environment will encourage this (Hizer, 2010). (For a complete description refer to Martin, Arendale, & Associates, 1991).

This method has been trialed in various forms at different postsecondary institutions (California State University, San Marcos n = 248 (Hizer, 2010), San Francisco State University n = 12,000 (Peterfreund, Rath, Xenos, & Bayliss, 2008)). Some studies have shown improvement of academic performance in students undertaking STEM courses (Hizer, 2010; Peterfreund et al., 2008), and participants in SI confidence levels were measured to be higher than non-participants (Hizer, 2010). At CSU, a form of supplemental instruction has been successfully used in non

STEM courses. (See Figures 2.1 and 2.2.) However, the number of students availing themselves of this facility is small compared to the overall number of students taking the course.

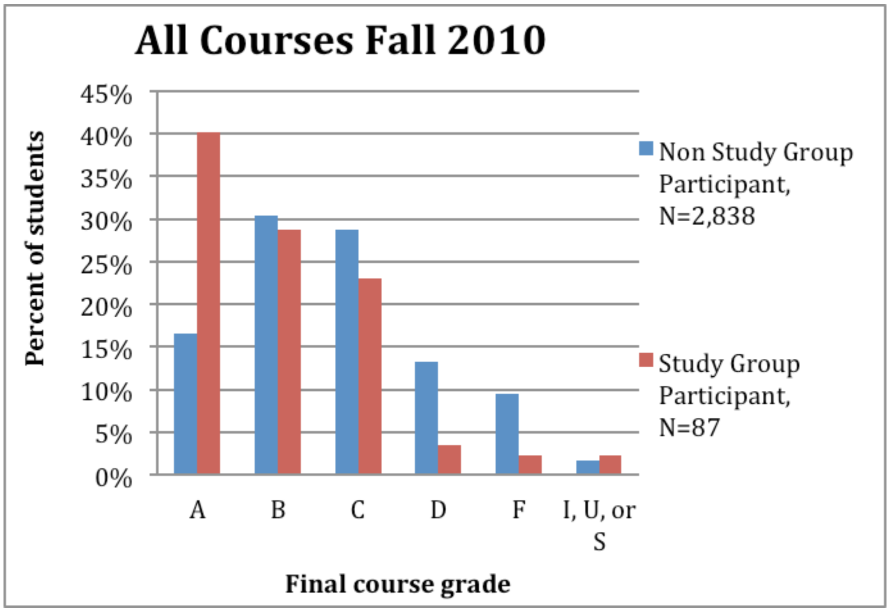


Figure 2.1. Compare final course grades of fall 2010 supplemental instruction group participants to non-participants.

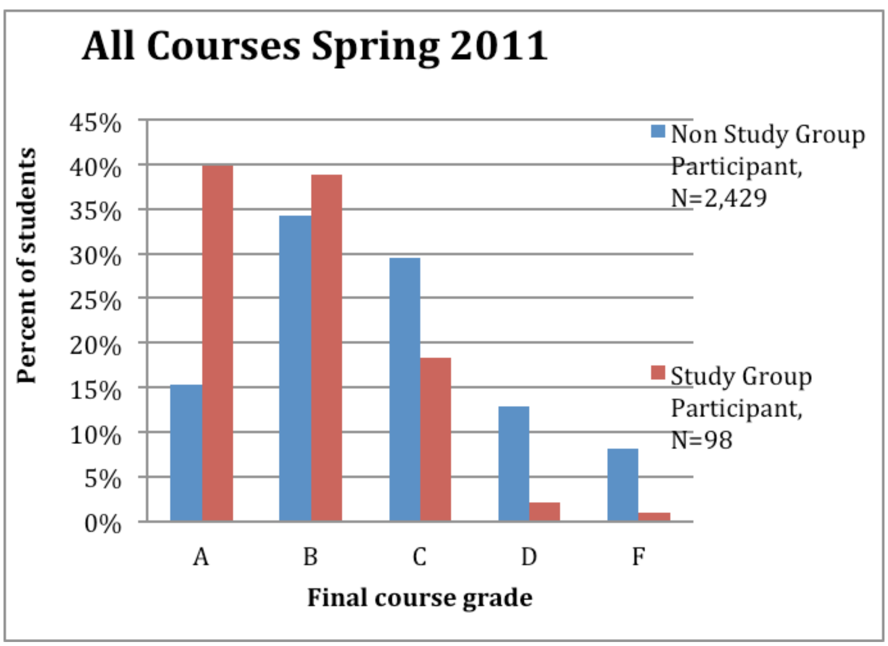


Figure 2.2. Compare final course grades of spring 2011 supplemental instruction group participants to non-participants.

Hockings (2009) cautioned that thirty percent of students do not respond to student-centered techniques. A Finnish study also identified that roughly a third of students are unaffected by changes in the delivery of a course, even more concerning is their identification of nineteen percent who reacted negatively to the change (Honkimaki, Tynjala, & Valkonen, 2004). Hockings' (2009) study used qualitative techniques to analyze videotaped data of a class she gave to 200 second-year degree and diploma students using student centered techniques, as well as interview data with the students from this course. Her analysis identified a group of students that either will only accept knowledge given by the instructor, or who lack the confidence that they can identify the right answer and express it adequately. Relative to this study, identifying if these students are in the at-risk group is needed. If they are, then a different strategy may be needed for these students.

Changing Outcomes for "At Risk" Students

The success of supplemental instruction may relate to how this technique addresses the transition of freshman college students from secondary education to postsecondary education rather than focusing only on the subject material of a particular course. However, it is a voluntary intervention. Those who volunteer will not necessarily be the ones at risk, or the groups that form may not necessarily be heterogeneous, or students may decide they are too time poor to maintain their interest in the group for the entire semester. A hybrid approach may be in order.

The University of Colorado at Boulder is not unique in using a pre-test to guide a student to the appropriate mathematics course (University of Colorado at Boulder, 2011a). A few examples are the University of Arizona (University of Arizona, 2012), New Mexico State University (University of New Mexico, 2012), Rose-Hulman Institute of Technology (L. Holder, personnel communication,7th November, 2011) among others. Certainly the aim of the MATH 180 intervention was to target only those students that needed an intervention, however, the selection process was four weeks into the semester and placed the student a semester behind in their program.

Focus on preparation for post-secondary education

"a good memory is not sufficient to pass examinations". (Hargreaves, 1996)

At CSU the PACe center offers self-paced pre-calculus instruction programs. Students intending to enroll in MATH 160 are required to either:

- Demonstrate they do not need to take these modules by providing documentation from their high school to indicate they passed their high school calculus course to a standard of "B" of higher, or passed the advanced placement calculus course to a standard of "3" or higher; or
- Complete six placements tests in algebra, trigonometry and logarithms to a satisfactory level; or
- Complete the self-paced online courses and then complete the six placement tests as above. (Colorado State University, 2012g)

Despite the placement tests, there is still a high fail rate in MATH 160. As noted above, there is a group of students who struggle to make the transition from high school to post-secondary studies. Many of the students struggling with freshman calculus at CSU had poor study skills (Reinholz, 2009). This is reinforced by a survey study of CSU sophomore students currently underway at CSU which highlights that students understand their survival of freshman and subsequent years depends upon their ability of organize themselves (L.A. Varela, personal communication, 11th November, 2011). Perhaps the students with poor study and time-management skills could be identified and targeted for an intervention.

Focus on persistence

> "…one of the first groups of students to be lost are those who have internalized the attitudes of teachers, parents and peers who confuse talent with achievement. Thus, students with strong ability in mathematics may, paradoxically, become the early casualties of the weed-out system." (Seymour & Hewitt, 1997, p. 86):

A good predictor of students' willingness to persist with their studies was a combination of interest in the course, ability to regulate study habits, and time management (high ambivalence correlated with low study continuance $B = -0.38$ and low achievement $B = -0.31$) (Van Bragt et al., 2011). Both the switchers and non-switchers in Seymour and Hewitt's (1997, pp. 92 - 99) ethnography blamed the pace of the course for their change to surface learning approaches. However, attempting to remedy this by altering the pace of the course needs to be done carefully to avoid the University of Canterbury experience of students still not giving the course the time it required (James, Montelle, & Williams, 2007). Hargreaves (1996) also noted that the longer a student persists with their studies, the more likely the student is to be using a deep approach. Perhaps students who persist with their studies are more intrinsically interested in the material, or the more interesting the topic of study becomes to the student.

In Seymour and Hewitt's (1997) ethnographic study on why students leave science, mathematics, and engineering courses, a significant number of students, who should have been capable of completing a degree majoring in either the sciences or mathematics, switched out because of an accumulation of events. Generally these events included frustration at low grades, enduring learning experiences they were not gaining anything from, and usually a "last straw" event. Other examples by McDade (1988) include students enduring public criticism of a publicly expressed opinion, as well as other students taking assignment scores as evidence of being "weeded out", rather than feedback or an indication of a lack of the student's understanding. This was mollified by Hagedorn (2005) who determined some of these students switch institutions rather than completely abandoning their chosen fields. Perhaps for some students their experiences in one course may impact their persistence in all other courses they are enrolled in.

Focus on the student

Swan and Barbuti (2010) recommend better counseling for students before they attempt their chosen course so that the student is better prepared for the amount of work that will be expected. Berry, Cook, Hill and Stephens (2011) suggest more guidance for students as to where they should focus their efforts, and van der Meer et al. (2010) also indicated time management skills in students especially needed to be developed. At CSU, students enrolling in a STEM major attend sessions where they are given advice on the appropriate course to attempt (CSU, 2012c). Further, students who have failed their first mid-term examination in certain courses known for a high failure rate (such as MATH 160) are identified on an online system via an "Early Grade Feedback" flag. If these students are freshman, they will be contacted either by email, mail, or in person and invited to attend a workshop designed to inform the student of the many different resources and programs the university has to offer to help them achieve the grades they want (CSU, 2012d). Despite this, the fail/drop rate at CSU for MATH 160 is still high.

The researcher's personal experience agrees with Wood and Lynch (2002), it is hard to motivate students to engage when they believe they have seen and covered the material before. At CSU, those who did well in high school calculus courses are encouraged to enroll in the second course in the calculus stream. However, when this option was discussed with some students enrolled in the first-course calculus in Fall 2009, they said they declined skipping ahead because they wanted an "easy option". Interestingly, not all of these students did as well as they thought they would in the course.

Anecdotally, trying to shock students out of their complacency has had some success (T. J. Penttila, personal communication, 7th December, 2006). However, this was done by giving an examination early in the semester in a system where examinations traditionally took place only at the end of the semester. CSU already gives an examination early in the semester, and although some students are nudged out of their complacency, there is still a high failure rate (Pilgrim, 2010; Reinholz, 2009).

If retention rates and pass rates are to be improved, students who are capable but are otherwise not doing well, or dropping out, need to be specifically targeted for an intervention as early as possible. Part of this dissertation will consider if there are clusters of students with particular common background variables that could be identified before or at the beginning of the semester. Then the student could be directed into a program more suited to their needs. The other part of this dissertation will focus upon the students who are failing and attempt to determine what these students perceive to be the impediments to their success. The results of both approaches will then be compared to determine if the insights from the qualitative analysis can be used to identify what other attributes students who are academically at risk might have.

CHAPTER III: RESEARCH METHODOLOGY

Research Design

Background.

The Calculus for Physical Scientists course (MATH 160) run by the Mathematics Department at Colorado State University (CSU), is a freshman course in the topic of Calculus run largely for students majoring in Engineering, Science (Physics and Chemistry) and Computer Science. It has a reputation for having a high fail rate. According to the MATH 160 course coordinator, forty percent of those who take this course will need to repeat it (Pilgrim, 2010).

Problem.

Students still continue to fail Math 160 at a high rate. The research problem was to investigate the different student attribute variables that predict, or seem to affect, grades for students taking a freshmen course in calculus.

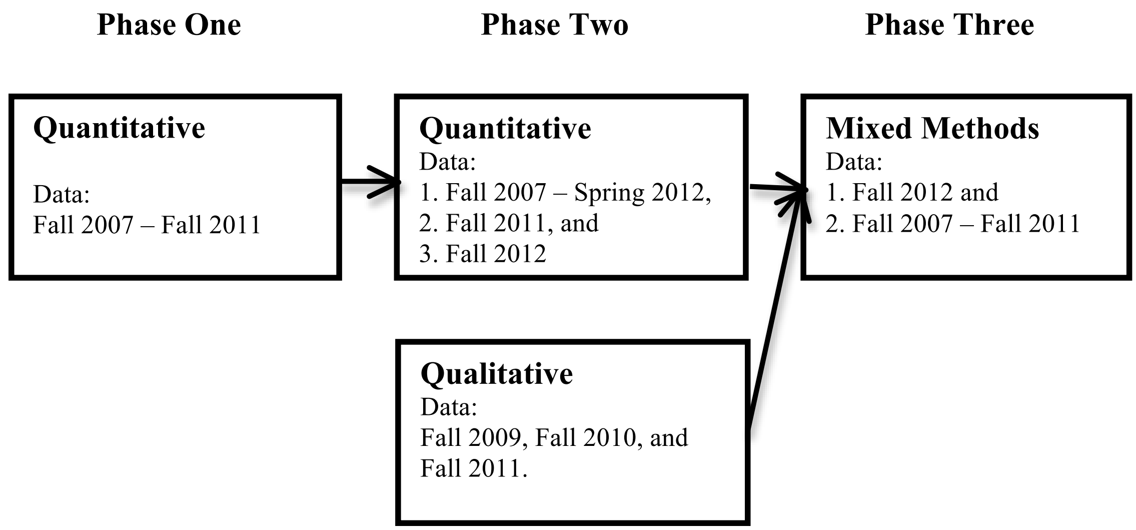
An explanatory sequential mixed methods design was used, and involved collecting quantitative data first and then explaining the quantitative results from insights gained in the qualitative analysis. In the initial quantitative part of the study, historical student data from Math 160 students at CSU were analyzed to identify groups of students who struggle with this course. Two surveys were also run on the Fall 2012 cohort as the literature suggested motivation and study strategies were additional variables to consider. For the qualitative part, past students of Math 160 were invited to relate their experiences in taking this course. Analysis of this data were used to confirm any influences of the variables identified in the quantitative part, as well as pick out other possible attributes that seem to influence success in Math 160. Finally, the Fall 2012 data were used to analyze different combinations affect on the ability to predict failure in this course.

Research Paradigm

A mixed methods sequential explanatory design was used in this study (Creswell & Plano-Clark, 2011). The purpose of doing this study was to better understand the common factors contributing to a high failure rate in MATH 160 'Calculus for Physical Scientists'. In Seymour and Hewitt's (1997) study, students who drop out of a course and those who remain were deemed very similar. Therefore, the aim of using a mixed methods approach was to attempt to better identify the students who, from their academic record, should be quite capable of doing the course but either do not achieve the grades they should or drop the course. The qualitative part of this study was used to isolate common characteristics of the students in danger of dropping out or failing. As such the qualitative paradigm will touch on being Constructivist (Crotty, 1998), whereas the quantitative part of the study will be Post Positivist (Crotty, 1998).

The Explanatory Sequential Design

This thesis has three parts. The initial part (phase one) is a quantitative exploration of the existing historical data on past students. Phase two has both a quantitative and a qualitative analysis. The quantitative analysis is on current students to determine how well any variables found in this and the previous phase predict the outcome of students in the MATH 160 course. The qualitative analysis explores the opinions and experiences of the students who have taken MATH 160. The last phase is mixed methods where the results from the quantitative and qualitative analyses in phase two are integrated and the quantitative data reanalyzed.



Sample and sampling.

For phase one, all students who completed MATH 160 from Fall 2007 to Fall 2011 (inclusive) were part of the target population. (n = 3,039, some will have attempted the course more than once.)

For phase two, the target population for the quantitative part consisted of the students enrolled in six sections of the Calculus for Physical Scientists I course (MATH 160) at Colorado State University (CSU) during the Fall 2012 semester. All students were given the opportunity to participate. The analysis from phase one will be linked to the data from this phase.

In fall semester this cohort can be up to 500 students, and in spring semester up to 300 students. The numbers of students attending the summer version of the course is dramatically less. The structure of the summer MATH 160 course is significantly different as well. The length of each lecture is longer, and the class meets five times a week for fewer weeks, whereas, the fall and spring semesters meet four times a week for 50-minutes classes. All tests and examinations are written by the instructor giving the summer course, unlike fall and spring, where the course coordinator does this for the cohort. The students attending the summer class would need to be examined separately, as the student's reasons for taking this course in the summer semester as well as the difference in the structure of the course could be quite significant confounding factors. Hence, the summer semester cohort was not analyzed. The spring semester cohort was also omitted, as this group historically contains a larger proportion of students who are repeating the course.

For the qualitative part, the target population consisted of students who completed the Calculus for Physical Scientists I course (MATH 160) at Colorado State University (CSU) during the Fall 2009, 2010, or 2011 semesters. Permission was obtained to interview at most 40 students (see Appendix B). For this study, thirteen students were interviewed, with a further 27 choosing to answer survey questions instead. (See Tables M8 and M9, Appendix M.)

For phase three, on the basis of the results from phase two, the Fall 2007 – Fall 2011 data and the Fall 2012 data were reanalyzed.

Data Sources and Collection Methods

Historical Student Data.

For phase one, student data were sourced from both the Registrar's Office at Colorado State University (CSU) and the 'Paced Algebra to Calculus electronically' (PACe) center based in the Mathematics Department at CSU. As per the letter of exemption from the Institutional Review Board's approval (see Appendix A), any information that could uniquely identify a student was removed. The Registrar's Office supplied any information they have for the student's: Colorado College of Higher Education (CCHE) index score, ACT scores (English, Mathematics, Reading Writing and Combined), SAT scores (Reading, Mathematics, Writing and Composite), as well as the major the student was enrolled in, their class, the college they were attached to, and the results of other subjects taken at the same time as the student did MATH 160. Placement test data raw scores were obtained from the PACe center.

Instrument choice criteria.

For phase two, an instrument was used to determine if other variables could be found that could be used as predictors for student success in MATH 160. For freshman college students, motivation and study strategies have been positively associated with a student's final grade ($p < 0.05$) (Ferla, Valcke, & Schuyten, 2009; Lynch, 2006; Lynch, 2010). Zimmerman (1990) also considered a student needed more than just motivation and a set of study skills for successful academic outcomes, they also needed the ability to self regulate so that the tasks needed to study are carried out. In a very small study ($n = 19$) of academically at-risk students at the Bronx Community College, Cukras (2006) identified an association between academic performance and the student's ability to self-regulate their organization and adherence to a study plan. Motivation, study strategies and self-regulation can be further broken down into subscales, some more useful than others.

Robbins et al. (2004) performed a meta-analysis on 109 studies extracted from both psychology and education literature that contained student study and outcome result data collected from college students studying any major, and attending four-year colleges or universities in the United States. Comparing various motivation and persistence theories, they classified nine psychosocial and study skill subscales, and determined if there were any significant correlations between these subscales and either student retention or grade outcomes. They found a moderate relationship was determined between: retention and academic goals (estimated true correlation = 0.340), retention and academic self-efficacy (estimated true correlation = 0.359), retention and academic related skills (estimated true correlation = 0.366), grade outcomes and academic self-efficacy (estimated true correlation = 0.496), and grade outcomes and achievement motivation (estimated true correlation = 0.303).

Several potentially suitable instruments to measure these constructs were found from literary searches and are briefly listed in Table 3.1. Each were considered, and the analysis given below.

Table 3.1
Instruments Measuring Student Motivation and Study Techniques

Name	Acronym	Basis
Learning and Study Strategies Inventory	LASSI	Based upon a 'student approaches to learning' (SAL) theory interrelating student motive to study with student strategies to study (Biggs, Kember, & Leung, 2001).
Study Process Questionnaire	SPQ	Based upon a 'student approaches to learning' (SAL) theory interrelating student motive to study with student strategies to study (Biggs, Kember, & Leung, 2001).
Meta-Cognitive Awareness Inventory	MAI	Based upon a theoretical framework of students' knowledge about their own learning (meta-cognition), (Schraw, & Dennison, 1994).
Self-Regulation Survey	SRS	Based upon the Motivated Strategies for Learning Questionnaire
Motivated Strategies for Learning Questionnaire	MSLQ	Based upon a cognitive and motivational theoretical framework (Self-Regulated Learning, SRL) (Pintrich et al., 1991a)

The Study Attitudes and Methods Survey (SAMS) (Sherman, 1991) and School Motivation and Learning Strategies Inventory (SMALSI) (Stroud, 2006) were also identified but are aimed at school age students rather than college age students so these two instruments were no longer considered.

The Learning and Study Strategies Inventory (LASSI) instrument (Weinstein & Palmer, 2002) has been utilized for a long time as a diagnostic tool, and is very detailed in what it could determine about the methods employed by a student to study a subject. Mental Measurements Yearbook (Yearbook 17) reports that although LASSI has internal consistency reliability with coefficient alphas for each scale ranging from .73 to .89, the authors do not provide empirical evidence for external validity (Weinstein & Palmer, 2002). Also, a number of studies have determined the items in the ten categories used to measure the LASSI scales relate to more than one construct, as well as to constructs other than those listed (Melancon, 2002; Prevatt, Petscher, Proctor, Hurst, & Adams 2006; Olaussen & Braten 1998). In relationship to this study, the LASSI scale has a limited ability to measure any motivation subscales. It is available for purchase through H & H Publishing and, as such, it is not possible to easily compare the instrument to alternatives. Its value as a group diagnostic tool would be costly to assess as it costs over $1,500 for a cohort of 500 students. If any individual student wanted to know how to improve their own study technique then they could be directed to this instrument, but it will not be considered further for this study.

The Revised Two Factor Study Process Questionnaire (Biggs, Kember, & Leung, 2001) is based upon a longer instrument (Study Process Questionnaire, SPQ), which was also developed by Biggs (Biggs, 1987). It was designed to measure the approach a student takes to studying. The study approach was seen to be a composite of both ‘motive’ for studying and the ‘strategy’ used to achieve any goals and so used as a basis for an instrument in this study.

Students will exhibit varying levels of these constructs depending upon their: background, ability, educational experiences, aims, as well as things beyond their control such as the expectations of the institution they are studying at, and the structure of the courses they have chosen (Biggs, 1987). A significant positive association (β = 0.27) between a deep learning approach and academic performance was measured when comparing study approaches used by third-year education majors to their academic performance at a university in the Pacific (Phan, 2006). There was no association between a surface learning approach and academic performance (Phan, 2006). This would indicate that a deep learning approach should be the aim for students wanting to be successful in their studies. However, a study analyzing first-year psychology students found students with low self-efficacy scores tended to change their learning styles to a surface approach over time (Prat-Sala & Redford, 2010). This is consistent with Hargreaves' (1996) initial observations on changes in student learning approaches between freshman and sophomore years, who found a significant increase in the number of students who use surface learning approaches between these years (Hargreaves, 1996). The revised instrument was tested on 495 undergraduate students representing a cross-section of faculties from a university in Hong Kong. (See Table C3, Appendix C for reliability Cronbach alpha scores).

***Pilot Instrument 1 description*.**

The instrument developed for this study was a combination of the Revised two-factor Study Process Questionnaire (R-SPQ-2F) (Biggs et al., 2001), the Indiana Mathematics Beliefs Scales (IMBS) (Kloosterman & Stage 1992), and the 'Mathematics is useful in daily life' scale developed by Fennema and Sherman (1976). (See Tables C1 & C2, Appendix C.) The IMBS instrument is based upon Kloosterman and Stage's (1992) idea that a student's beliefs about mathematics can hinder that student's learning of the subject. The items for their instrument were generated from a literature review and earlier instruments developed by Kloosterman (1992). A panel of experts then reviewed this list of items and the items remaining were tested for validity and reliability on a population of college students (Kloosterman & Stage 1992). A modified version of the IMBS scale was used for CSU MATH 160 students in 2009 and 2010. Three of the constructs associated with this scale were statistically significantly correlated to the student's final grade (Pilgrim, 2010). On this basis, the constructs: 'I can solve time-consuming mathematics problems'; and 'Understanding concepts is important in mathematics' (Kloosterman & Stage 1992); as well as the construct 'Mathematics is useful in daily life' (Fennema & Sherman, 1976) were included in the first pilot instrument in order for a local basis for comparison of the reliability and validity measurements. (See Table C5, Appendix C.)

The IMBS constructs have six questions per construct, so each construct score can be from 6 – 30. Half of the questions in each construct are worded negatively and must be reversed before analyzing the data. The 'Mathematics is useful in daily life' construct also has six questions. Each construct was scored separately. The scale is phrased 'strongly disagree', 'disagree', "uncertain', 'agree', and 'strongly agree'. (See Appendix G).

All of the twenty items from the R-SPQ-2F instrument were included with minor changes. Method questions included items such as: "My aim is to pass this course while doing as little work as possible" and "I work hard at my studies because I find the material interesting". Strategy questions included items such as: "I only study seriously what's given out in class or in the course outlines" and I test myself on important topics until I understand them completely".

The original five-point Likert scale uses the phrases: "this item is never or only rarely true of me", "this item is sometimes true of me", "this item is true of me about half the time", "this item is frequently true of me", and "this item is always or almost always true of me". These were altered to match the Likert scale used by IMBS. Tables C1 and C2 in Appendix C describe the subscales of this instrument in detail, and Table C4 in Appendix C cross-references which items are summed to give the totals for each construct.

All items were interleaved and not grouped. This is consistent with recommended procedures for administering the IMBS instrument (Kloosterman & Stage, 1992). This also helps avoid 'socially acceptable' responses being given, which may happen if grouping the questions lead the student to work out what construct was being measured.

A pilot study of this instrument was performed in the first week on the entire Fall 2011 cohort (n = 412 usable responses out of 435 collected). Six of the nine constructs used in the pilot instrument had statistically significant correlations to the student's final grade at either the .05 or .01 level, but even these correlations were smaller than typical according to Cohen (1988) with r ranging from 0.12 to 0.20. (See Table C6, Appendix C.) Perhaps the instrument was run too early in the semester and so the responses reflected student's intent rather than what they did. Immekus and Imbrie (2010), after analyzing the R-SPQ-2F instrument on students from a large midwestern university in the United States, did caution against using this scale on a population similar to theirs, as their results indicated this instrument did not generalize to this population. Although CSU is not considered to be in the Midwest of the US, it does have a population similar to the one analyzed by Immekus and Imbrie (2010). This instrument will not be pursued further.

Pilot Instrument 2 description.

The Self Regulation Survey (SRS) was developed specifically for post-secondary students. It was designed to measure a student's ability to control the learning tasks and activities they undertake to study a course (Briley, 2008). Briley's (2008) study recognized that the student had moved from the high school environment where their time had been mostly organized for them, to the post-secondary environment where the student was required to organize their time themselves. The aim was to measure how successfully this transition was made. It would be interesting to utilize this, however as it is based upon the Motivated Strategies for Learning Questionnaire (MSLQ), which has more supporting analysis, the MSLQ was selected instead.

MSLQ was developed and tested on a sample of college students (*n* = 356) from a cross-section of different courses. Pintrich (2004) developed a conceptual framework for student learning motivation and self-regulation based upon theories of self-regulated learning (SRL) and student approaches to learning (SAL). Pintrich identifies four phases as well as four areas affected by each phase (see Table 3.2), but these phases do not necessarily occur sequentially, nor do all phases inevitably need to happen for student learning to occur (Pintrich, 2004).

Muis, Winne, and Jamieson-Noel (2007) compared the three instruments of Learning and Study Strategies Inventory (LASSI), Motivated Strategies for Learning Questionnaire (MSLQ), and Meta cognitive awareness inventory (MAI). (See Table 3.3.) They compared the subscales that could be identified with self-regulation in all three of the above instruments (*n* = 318) using a population of undergraduate students who each completed all three instruments as part of a larger study (Muis et al., 2007). There was no pattern of high correlations across the self-regulation subscales found. As each instrument does come from a different theoretical basis, Muis et al. (2007) indicate this verifies each instrument does measure slightly different facets of self-regulated learning. Noticeably, MAI does not have any subscales measuring any part of the motivation construct. The MAI instrument is more widely used as a cut down version in studies for school children. So it will not be considered further either.

MSLQ is in the public domain (Duncan & McKeachie, 2005, p. 120). Mental Measurements (Yearbook 13) reports some subscales have low reliability and validity data (Pintrich, Smith, Garcia, & McKeachie, 1991b). Even the instrument authors admit that the goodness of fit to their model is not brilliant (Pintrich et al., 1991a); however, the Cronbach alpha data for the subscales of interest in this study are adequate (ranging from 0.62 to 0.90). This instrument measures motivation subscales in quite some detail as well as self-efficacy, self-regulation and study skills subscales (see Pintrich et al. (1991a) for full description). This more closely covers this study's interest so this instrument was piloted. (See Appendix H.)

Table 3.2
Phases and Areas for Self-Regulated Learning.

	Areas for regulation			
Phases and relevant scales	Cognition	Motivation/Affect	Behaviour	Context
Phase 1 Forethought, planning, and activation	Target goal setting Prior content knowledge activation Metacognitive knowledge activation	Goal orientation adoption Efficacy judgements Perceptions if task difficulty Task Value activation Interest activation	Time and effort planning Planning for self observations of behaviour	Perceptions of task Perceptions of context
Phase 2 Monitoring	Metacognitive awareness and monitoring of cognition	Awareness and monitoring of motivation and affect	Awareness and monitoring of effort, time use, need for help Self observation of behaviour	Monitoring changing task and context conditions
Phase 3 Control	Selection and adaptation of cognitive strategies for learning, thinking	Selection and adaptation of strategies for managing, motivation and affect	Increase/decrease effort	Change or negotiate task
Phase 4 Reaction and reflection	Cognitive judgements Attributions	Affective reactions Attributions	Choice behaviour	Evaluation of task Evaluation of context
Corresponding MSLQ Scales (variable name)	Reh, Elab, Org, Crit, Mcg	Intr, Extr, Tskv, Cont, Slfef, Tanx	Eff, Hsk, Tsdy	Prlrn, Tsdy

Note. Adapted from Table 1, Pintrich (2004), p. 390.

Table 3.3.
Comparison of constructs and subscales for LASSI, MSLQ and MAI instruments.

LASSI	MSLQ	MAI
Skill Information Processing – this relates to what the student does to facilitate understanding and later recall of what they have learned. Selecting main ideas – the ability to pick out the important bits of what is being presented. Test Strategies – preparation for a test **Will** Anxiety – how tense the student is when approaching a required task Attitude – towards study, school, and performing the tasks at hand Motivation – acceptance of personal responsibility for their learning. **Self-regulation** Concentration – ability to direct attention to study related tasks Time Management – creating of a study schedule and using it. Self-testing – how much the student uses this strategy. Study Aids – their use of study aids, either created themselves or developed by others.	**Motivation** Intrinsic Goal Orientation – Valuing task because it is interesting in itself. Extrinsic Goal Orientation – Valuing task as it has rewards – e.g. grades. Task Value – Valuing task as it is useful (or not). Control Beliefs – Expect to have control over the amount of effort put in and rewarded for effort. Self-Efficacy – Expect to be able to perform the task. Test Anxiety – Affect of worry and anxiety on ability to do task. **Learning Strategies** Rehearsal – Simple memorization. Elaboration - Understanding (paraphrasing, note-taking etc.) Organization - Selecting the main ideas in task. Critical Thinking – Apply previous knowledge to new situations. Self-Regulation – Planning, monitoring, regulating study tasks. Time and Study Environment – Time management. Study Environment Effort Regulation – Commitment to completing task. Peer Learning – Collaboration with peers. Help Seeking – Knowing when they need to seek help and knowing where to get help.	**Knowledge of Cognition** Declarative knowledge – knowledge about ones skills and abilities as a learner. Procedural Knowledge – how to implement learning strategies. Conditional knowledge – when and why to use learning strategies. **Regulation and Cognition** Planning – allocating resources prior to learning. Information Management – organizing; elaborating; summarizing; selective focusing Monitoring – assessing ones learning or strategy use Debugging – strategies used to correct performance or comprehension errors Evaluation – analysis of strategy effectiveness after the learning tasks.

The Motivated Strategies for Learning Questionnaire (MSLQ) is an 81-item instrument developed by Pintrich et al. (1991a) to measure a college student's motivation and use of different learning strategies. The instrument uses fifteen subscales, which have been grouped into two categories 'motivation' and 'learning strategies'. (See Table D1, Appendix D.) Motivation questions include items such as "In a class like this, I prefer course material that really challenges me so I can learn new things" and "I have an uneasy, upset feeling when I take an exam”. Learning strategy questions include items such as “I make good use of my study time for this course” and “I find it hard to stick to a study schedule”.

The MSLQ instrument uses a seven point Likert scale. This scale was altered for use in the current study by anchoring all seven-points so each point of the range from ‘not at all true of me’ to ‘very true of me’ was explicitly fixed. The original instrument was only anchored at each end, which the authors claimed was a benefit (Pintrich et al, 1991a), however, other researchers have criticized the instrument for this (Pintrich et al. 1991b). In this study, the researcher deemed fixing all seven points to be less ambiguous for the students who would complete the instrument.

Eight of the items are reversed scored. Norms are not provided, as it is assumed these may be course dependent. However for all subscales, except ‘test anxiety’, a higher score is better than a lower score.

A pilot study of this instrument was performed on the Spring 2012 cohort (228 usable responses out of 231 collected). It was run in the fifth week of the semester (after the first mid-term examination) for the entire cohort (n = 313). Analysis of this data gave similar Cronbach alpha scores for each subscale as documented by Pintrich et al. (1991a) (See Table D1, Appendix D.) The ‘Task Value’ subscale was the only subscale where the kurtosis value was not optimal. Several of the constructs had statistically significant correlations to the first mid-term examination score. (See Table D2, Appendix D.)

As the spring cohort are reputed to contain a higher number of students who repeat, the above analysis was repeated breaking the data into two groups of students: those repeating the course and those not repeating. For the students new to the course, the correlation data did not change very much from the table above. For the students who were repeating the strongest correlation to the first mid-term examination score was for the 'Help Seeking' subscale (n = 33, r = .49). The version of the instrument run in Fall 2012 is in Appendix J.

Other instruments

PACe Center Placement Tests

Six placement tests are run by the PACe Center at CSU covering pre-calculus topics such as algebra, trigonometry and logarithmic and exponential functions. The raw scores, or a combination of them, from these tests were used as part of the prediction analysis.

Examination Results

The scaled scores from the mid-term and final examinations were used to test the prediction variables found in phase one. According to Reinholz (2009), the results of the first mid-term test had a correlation of r = .7 to the final results student's achieve.

Mathematics Background Survey

A 'Mathematics background' survey on the student's own mathematical experience was conducted as homework in the second week of the semester. In this instrument were items requesting demographic information that was not available from student records. The questions were formulated after analyzing mathematical background surveys from prior semesters (Spring 2011 and Fall 2011) and analyzing responses to an essay question given to two sections of the Fall 2010 cohort. (See Appendix I.)

Items included were:

- Student Number: (to ensure they were compensated for their time and to link to first mid-term examination results)

- Minimum grade they require in MATH 160. (For example: students enrolled in the open engineering option will require a 'B' in MATH 160. Students enrolled in other courses may only require a 'D'.)
- Do they live on or off campus?
- Average hours per week spent on mathematics homework at high school.
- Average hours spent preparing for a test at high school.
- Average hours per week spent on studying mathematics (other than for the above reasons) at high school.
- How easy do you find mathematics? [] very easy []easy [] some parts easy, other parts hard [] not easy []can pass with tutoring [] a compete struggle.
- Size of last high school attended [] small (less than 400 students) [] medium (400 – 2000) [] large (more than 2000 students)
- Opinion of quality of mathematics teaching in high school [] low [] OK [] Excellent
- Prior experience with calculus:[] none [] high school [] college course but not MATH160 [] repeating MATH 160.
    - Date completed last calculus course.
- A list of other subjects currently enrolled in.
- List three qualities you believe a person requires to pass mathematics at university level.
- List the qualities you believe you have.

Qualitative Data Sources

As part of the qualitative analysis, students who took MATH 160 in Fall 2009, 2010, and 2011 were invited, via email, to either attend an interview or complete a survey. (See Appendix

K for a copy of the invitation and Appendix L for the survey questions). Common questions that were asked in the individual interviews were:

- Did they chose a major and then CSU, or CSU and then the major they enrolled in?
- What was their understanding about the level of work required for the major they enrolled in? Are they remaining with their chosen major?
- What did they expect this mathematics course to entail? What was their expectation for studying this course? How did they study the course?
- If they failed the course, what lead to their decision to stay/drop?
- What would they change about the course?
- Knowing what they know now, if they could have given themselves advice before they started the course, what advice would they give?

Collection methods.

Permission was sought to have students participate in this study. This was set up as part of the Mathematical Background survey that was given in the second week of the semester as part of their first homework exercise. All freshman students are encouraged to take the PACe placement test. After the cut-off date for completing this test, the raw data were requested from the PACe center staff.

The Math 160 mid-term examination data were collected during the semester.

The MLSQ survey data were collected as part of a homework assignment after the first mid-term examination. Although this missed the students who withdraw either before or just after the first mid-term examination, it gives the student time to settle into a study routine, and answer the questions in the instrument relating to how they do study mathematics, rather than how they think they should study mathematics. From what was learnt in the initial pilot study the

MSLQ subscales that were used in the second pilot study were: the self-efficacy for learning and performance, control beliefs, test anxiety, effort-regulation, rehearsal, elaboration, organization, time and study environment, and help seeking. The survey collection was set up via online survey software. When the modified IMBS instrument was administered in Fall 2009 and Spring 2010, the students were compensated for their time by allocating ten points of their forty-point total homework assignment to the survey. They were given this regardless of whether or not they agreed to participate in the modified IMBS survey and regardless of how well they filled in the survey. The same was done here, however, students who choose not to be part of the study were given a standard homework problem as an alternative to complete. The length of time needed to complete the homework problem was attempted to take roughly the same length of time to complete as the survey instrument.

The Likert scale data were extracted from the survey software and entered into a commercial statistical software package. Reliability tests were run again to confirm the results from the pilot tests. The Cronbach's alphas were compared to the data available for MSLQ scales and the pilot study and are reported in a comparison table. (See Table D1, Appendix D.)

The interview data were collected in a seating area of CSU. Consent forms, separate from the original consent forms, were completed by the specific students who participated in this part of the study. The interviews were recorded on to a dictaphone and later transcribed.

Research Questions and Data Analyses

The purpose of this dissertation was to explore ways of determining if students at risk of failing or dropping MATH 160 could be identified early, and for those who do fail or drop the course, to investigate the student's perspective as to what went wrong. In order to do this analysis ,the following research questions were examined:

Research question 1: Are there any common traits exhibited by students who fail, or withdraw from the MATH 160 course?

Research question 2: Are there combinations of variables that can predict if a student will succeed, or fail, in MATH 160?

In order to answer this question the following sub-questions were examined:

a) Which variables identified in phase one are statistically significantly associated to success in MATH 160?
b) What percentage of the group who failed the first mid-term MATH 160 examination was predicted to fail based upon predictor variables? Of those students advised to take the intervention course was their success rate improved?
c) Which, if any, of the subscales of the Motivated Strategies for Learning Questionnaire (MSLQ) are statistically associated with success in MATH 160?
d) Can a student's results in the first MATH160 mid-term examination course be predicted from a combination of predictor variables as identified above?

Research Question 3: What kind of association (if any) is there between students persisting with the MATH 160 course and the predictor variables identified previously combined with the student's results from their first mid-term examination in MATH 160?

In order to answer this question the following sub-questions were examined:

a) Can a student withdrawing from the MATH 160 course be predicted from the student's result ("D", or "F") in the first MATH 160 mid-term examination and other variables as predictors?

b) Can a student walking away from the MATH 160 course be predicted from the student's results ("D", or "F") in the first MATH 160 mid-term examination and other variables as predictors?

Research question 4: How do the students perceive their experiences of MATH 160?

Research question 5: What results emerge from comparing the quantitative data predicting a student's success, or failure, in MATH 160 with the qualitative analysis of the student interviews?

CHAPTER IV: RESULTS

The purpose of this study was to investigate students who are failing the freshman calculus course MATH 160, and attempt to identify any common themes so that an appropriate intervention might be offered. Results will be categorized according to the three research phases and by research question.

Phase One Results

The aim of the first phase is to find any common traits students who fail or withdraw from the MATH 160 course may have.

Research question one: Are there any common traits exhibited by students who fail, or withdraw from, the MATH 160 course?

To answer this question student data were requested from both the Registrar's Office at Colorado State University (CSU) and the "Paced Algebra to Calculus electronically" (PACe) center based in the Mathematics Department at CSU. As per the letter of exemption from Institutional Review Board approval (see Appendix A), any information that could uniquely identify a student was removed. The Registrar's office supplied any information they had for the student including: Colorado College of Higher Education (CCHE) index score, ACT scores (English, Mathematics, Reading Writing and Combined), SAT scores (Reading, Mathematics, Writing and Composite), as well as the major in which the student was enrolled, their college, their class, and the results of other subjects taken at the same time as the student taking MATH 160 for the semesters Fall 2007 through to Fall 2011.

From the PACe center, placement test data raw scores for six tests, covering algebra, trigonometry, logarithmic, and exponential functions, were received. All incoming students are required to take this Mathematics Placement test. This is waived for students who achieve a "3", “4”, or “5” on the AP Calculus examination. However, students who have taken the AP Calculus examination are encouraged to take the placement test, as their AP Calculus scores may not be known by the time they are trying to enroll in various subjects. The student is allowed to take this test once remotely, and twice on campus in a proctored environment (Colorado State University, 2012c).

The sum of the scores from all six tests, for each date these tests were taken, was calculated for each student. A correlation matrix was calculated to determine which score had the strongest correlation to the final examination grade among these possibilities: total score from unproctored test, total score from proctored test, total score from first time test was taken, total score from the last time the test was taken, and a score which only included the scores from the algebra tests. The strongest correlation was found with the score recorded the last time the student took the test, and thus, is the score referred to for the remainder of this study as the aggregate PACe placement score.

In Fall 2010 and Fall 2011, students in the Engineering College were given the option to have their grade recorded as either “S” for satisfactory, or “U” for unsatisfactory. The Mathematics Department was able to provide the original letter grade of the 145 affected students before encryption and analysis was attempted.

The following data were removed before analysis:

- Students attached to sections 732, 733, and 734. These are high school students whom are graded by their teachers and so have not gone through the standard MATH 160 course and assessment.
- Students attached to section 888. These students just do the examinations and so have not gone through the standard MATH 160 course.

- Sections W00, W01, W02 are lab sections attached to MATH 160 and which the student is required to enroll in concurrently. These sections do not receive a grade.

At CSU, a student who attains an unsatisfactory grade in a course has a limited option to "repeat/delete" their results. If the student chooses this option, the result of the failed course is removed from their grade point average calculation once the results of the retaken course is available. The grades for "repeat/delete" students are prefixed with an "R". What constitutes an unsatisfactory grade depends upon the student's major. For example, a student enrolled in Mechanical Engineering needs to achieve a "C" or higher in MATH 160 (Colorado State University, 2012e), whereas a student enrolled in an undeclared option and who is trying to transfer into engineering will need to achieve a "B" or higher grade.

The letter grade received by the student was translated to a separate numeric variable so statistical tests could be run. (See Table 4.1.).

Table 4.1.
Letter Grade Translation.

Letter Grade	Numeric Equivalent
A+	4
A	4
A-	3.667
B+	3.333
B	3
B-	2.667
C+	2.333
C	2
C-	1.667
RC	2
D	1
RD	1
F	0
RF	0
I or AU	missing

Note: Adapted from "GPA Calculation" Colorado State University, 2011b, http://registrar.colostate.edu/gpa-calculation. Retrieved October 24th 2011.

Although any data that might identify the student have been removed, the student identifier was replaced with another number that cannot be linked back to the original student, so if the student's information appears more than once, then it means the student is repeating this subject. A summary of the data analyzed is in Table 4.2.

Table 4.2
Summary Student Data.

Semester	Students who completed MATH 160	Students with CCHE data	Students with ACT data	Students with SAT data	Students with PACe center data
Fall 2007	390	257	294	132	319
Spring 2008	222	133	146	81	186
Summer 2008	32	16	20	10	23
Fall 2008	366	314	306	144	283
Spring 2009	225	187	187	74	180
Summer 2009	29	13	18	7	15
Fall 2009	414	365	338	150	307
Spring 2010	208	171	165	56	163
Summer 2010	42	22	25	9	27
Fall 2010	446	397	377	153	306
Spring 2011	229	169	162	68	164
Summer 2011	48	24	21	8	38
Fall 2011	388	337	309	136	287
Total	3039	2405	2368	1028	2298

To investigate if there were any statistically significant associations between the student's ACT scores, SAT scores, CCHE index scores, or aggregate PACe placement scores and their final grade, a correlation matrix was calculated. All correlations were statistically significant ($p < 0.01$) with the Pearson r values for the correlations to final grade ranging from 0.17 to 0.38. (See Table M1, Appendix M.) The largest correlated r values to final grade were with the CCHE index and the aggregate PACe placement score ($r = 0.38$ for both). Therefore these two variables were made the focus of further analysis.

Summary results of the data have highlighted differences between fall, spring, and summer semester cohorts. The bulk of the students attending this course come through in fall and spring semesters, so the student data for these semesters were grouped for analysis. These data were broken down by year and the number of students who passed versus those who failed was counted. Those who failed were further broken down into the number who failed one, two or more other courses in the same semester. The data were then regrouped and analyzed by college. A summary of the percentage of students who either fail or drop the course is in Table 4.3.

Table 4.3.
Percentage of Each Cohort that Either Dropped or Failed the MATH 160 Course.

Cohort	Calculate %F	Calculated %D	Calculated % DFW	(% include MATH 180 students.)
Fall 2007	23.59	7.18	37%	
Fall 2008	22.68	18.31	51%	
Fall 2009*	18.84	17.15	40%	(45%)
Fall 2010*	15.47	13.68	33%	(39%)
Fall 2011	18.04	14.18	42%	
Spring 2008	23.42	6.76	39%	
Spring 2009	24.89	16.44	50%	
Spring 2010	24.52	16.83	36%	(51%)
Spring 2011	28.82	10.48	49%	

Note. In Fall 2009, Spring 2010, and Fall 2010 students who failed the first mid-term examination were invited to change to the intervention course MATH180. The numbers on the right in brackets reflect these students included in the "DFW" percentage calculation. The actual value would be somewhere in between.

The number of students who withdrew was calculated by comparing the number of students per semester appearing in the data from the Registrar's Office to the data recorded at the Mathematics Department at CSU of the number of students who took the first mid-term examination in each of the semesters.

Other Classes.

Looking at the breakdown of the number of students who passed versus those who failed, a noticeable portion of students were failing more than just MATH 160. (See Figures 4.1 and 4.2.)

Among students who were failing more than MATH 160, two other subjects appeared to be failed regularly as well: General Chemistry 1, and Physics for Scientists and Engineers 1.

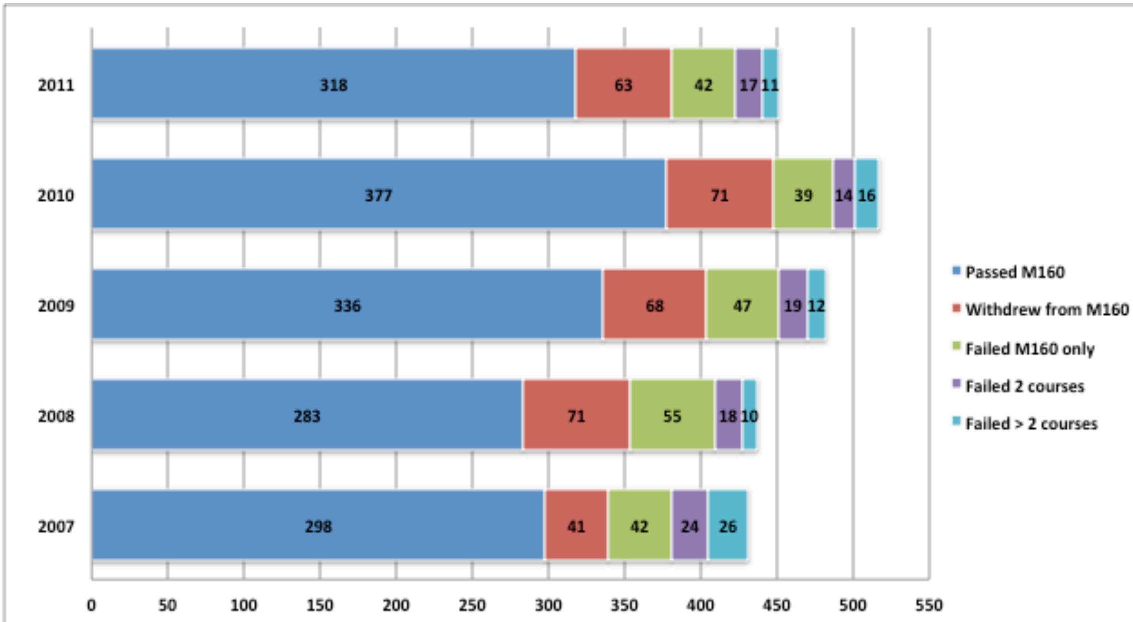


Figure 4.1. Break down by year of student numbers who pass or fail ("F") MATH 160 in fall, breaking out those who fail other subjects as well. The 2009 and 2010 student withdrawal data include students who transferred to the MATH 180 intervention course.

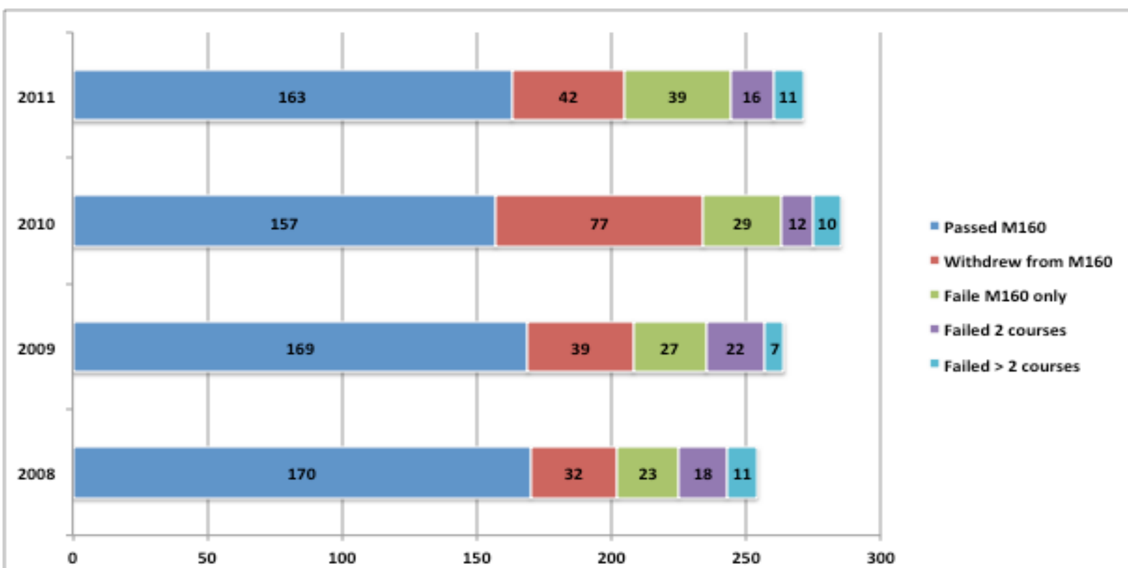


Figure 4.2. Break down by year of student numbers who pass or fail MATH 160 ("F") MATH 160 in spring, breaking out those who fail other subjects as well. The 2010 student withdrawal data include students who transferred to the MATH 180 intervention course.

By College.

The data by college gave different results for fall and spring semesters. (See Figure 4.3.)

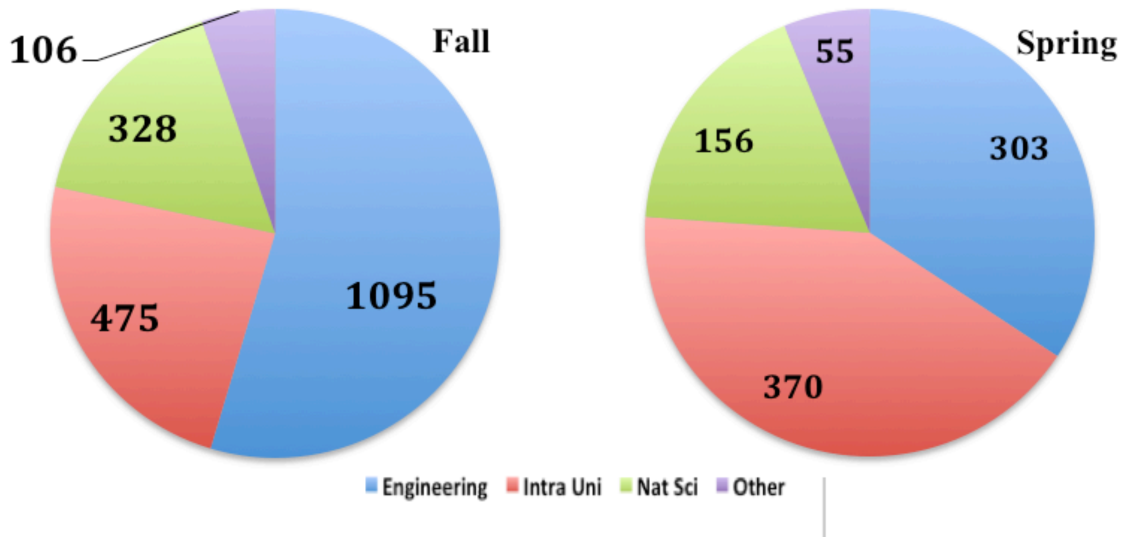


Figure 4.3. Break-down by college of students taking MATH 160 in fall and spring semesters.

Further, in the combined fall semester's data, students attached to the "Intra University" (IU) college represented twenty three percent of the cohort, and then fifty percent of the students who attained "D" or failed, whereas in spring these students represented forty one percent of the cohort, and thirty eight percent of the students who attained a "D" or failed (see Figure 4.4 and 4.5.). The IU college represents students who either do not know where they want to specialize, or did not achieve the required entry score for their degree. If these students are aiming at entry into engineering, they require a "B" or better grade in MATH 160.

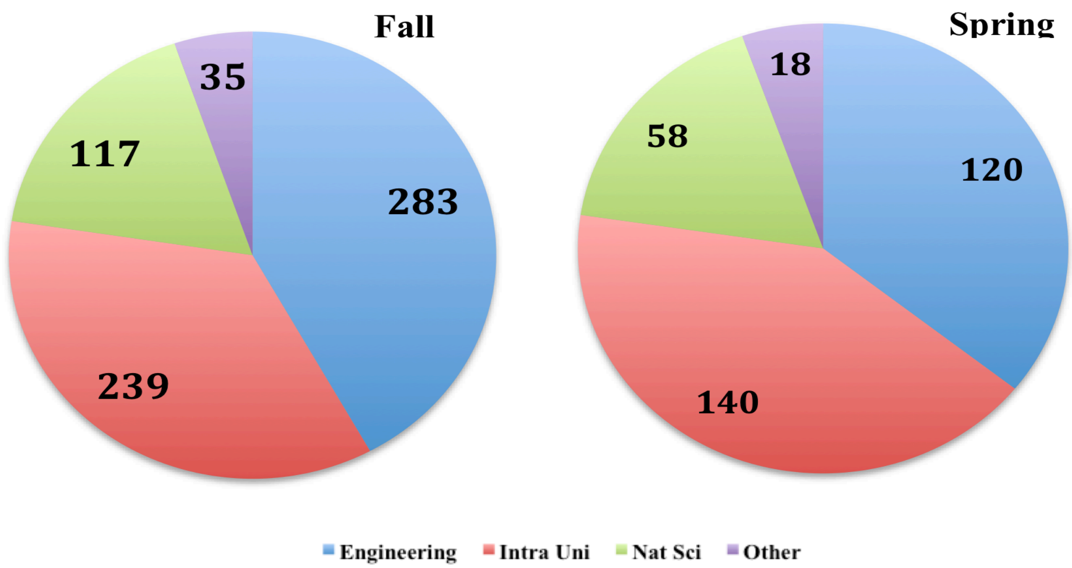


Figure 4.4. Break-down by college of students with a "D" or "F" as their results in MATH160 in fall and spring semesters.

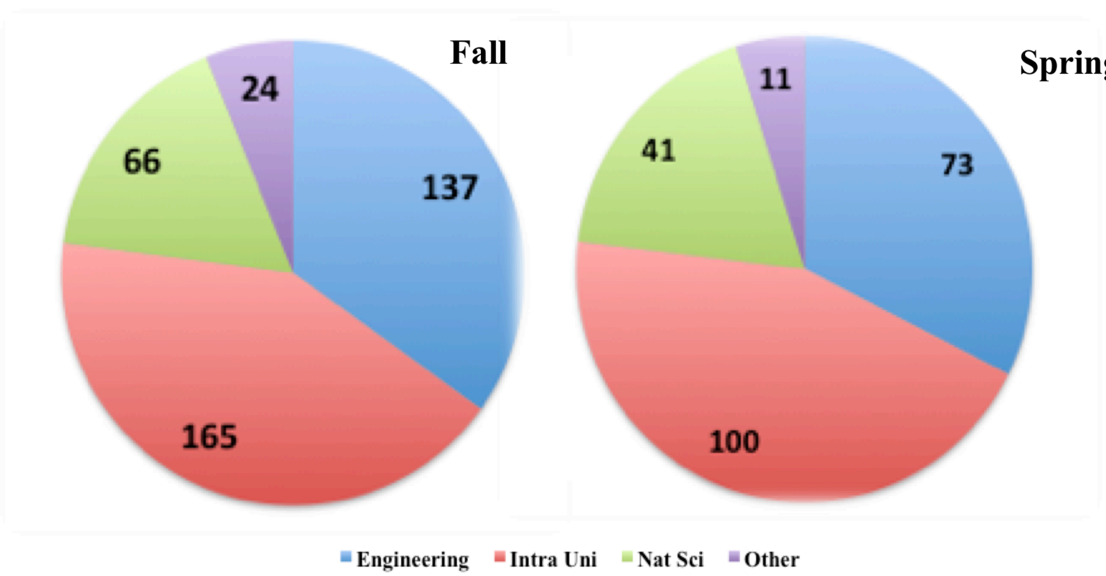


Figure 4.5. Break-down by college of students who failed MATH160 in fall and spring semesters.

Further, when looking at the percentage of students who withdraw from the MATH 160 course in Fall 2011, again the Intra University college has the highest withdrawal rate (see figure 4.6). Data on who formally withdrew from the MATH 160 course was not supplied by CSU's Registrar's Office. To determine the number of students that had withdrawn from MATH 160 in a semester examination 1 data provided by the course coordinator was compared to the final grade data from the Registrar's Office. For this study, the difference between these numbers represents the number of students that withdrew.

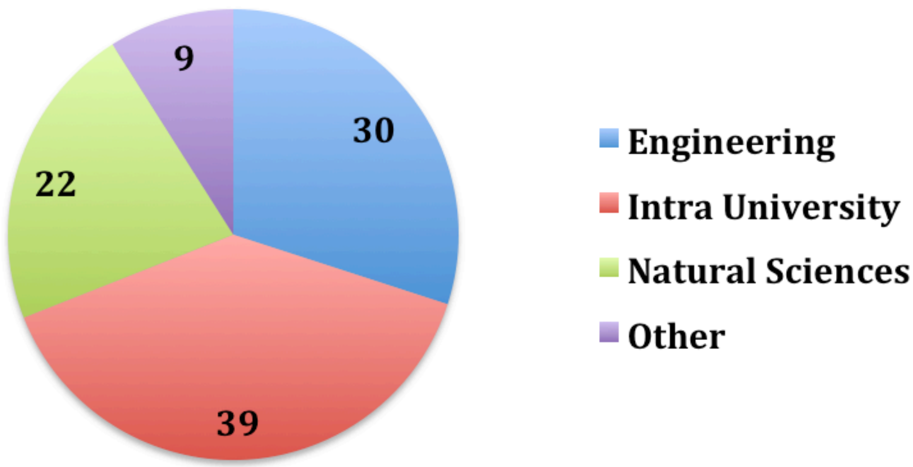


Figure 4.6. Break-down by college of students who withdrew from MATH 160 in Fall 2011.

Time of Day.

The data were combined with data from Spring 2012 and then reanalyzed by semester. Initially, the instructor was included as a variable in the analysis. However, not all instructors teach MATH 160 more than once, and so this reduced the power of the statistics available for analysis. Further, there were a number of instances where an instructor had taught MATH 160 more than once, and the student's results in the different semesters taught by that instructor were radically different. For example: the instructor who taught the eight a.m. section in 2010 also taught the one p.m. section in 2011. In the former section the percentage fail rate was nine percent and in the later, twenty percent. Barclay's (2012) study found no statistically significant correlation between examination scores and the instructor's availability and ability to effectively communicate, so at this point the time of day the section ran was considered instead. Instructors who have taught MATH 160 more than once rarely have done so at the same time of day.

Surprisingly, in the fall semester, ten a.m. and eleven a.m. appeared to have the highest failure rates. In these two time slots, the average fail rate ranged between 30 to 35 percent, compared to the eight a.m. or nine a.m. class where the range was between 15 and 18 percent (See Table 4.4.). The differences between the mean final grade for each class time was statistically significant as well ($F(8,1993) = 4.96$, $p < .01$). Table 4.5 shows the means and standard deviations by class time. Post hoc Bonferroni tests indicate the ten a.m. class differ significantly in grades from the eight a.m. ($p < .01$, $d = .51$), nine a.m. ($p < .01$, $d = .61$), noon ($p < .05$, $d = .36$), and two pm ($p < .01$, $d = .21$) classes. The eleven a.m. class differed significantly in grades from the eight a.m. ($p < .05$, $d = .60$) and nine a.m. ($p < .01$, $d = .47$) classes. This was not evident in the spring data. (See Table 4.6.)

Table 4.4
Percentage Fail and Percentage Fail and "D" Rates for Fall Semester.

Fall	**8 am**	**Large 9 am class**	**Small 9 am class**	**10 am**	**11 am**	**12 noon**	**1 pm**	**Large 2 pm class**	**Small 2 pm class**	**3 pm**	**4 pm**
Average %F	15.91	15.2	18.07	30.42	36.67	21.23	20.94	12.93	16.55	19.61	18.23
Weighted Average %F	15.69	14.98	17.74	30.81	34.09	20.1	20.93	16.44	15.56	19.71	18.25
Range %F	10.91	8.41	6.72	22.15	13.33	20	13.79	11.97	22.54	25.04	7.52
Average %DF	27.43	28.12	32.56	45.37	51.67	31.23	37.16	31.46	34.97	30.69	35.97
Weighted Average %DF	26.8	28.02	32.26	45.46	48.86	29.9	36.74	31.25	33.33	29.93	35.77
Range %DF	23.31	8.61	6.3	33.08	3.33	31.43	21.81	11.7	41.88	33.44	28.52

When examining what students who take these classes might have in common, the only things that stand out is the higher numbers of students who were attached to the Intra University college, and the number of students who were repeating the course in the ten a.m. and eleven a.m. classes. (See Table 4.7.)

Table 4.5

Means and Standard Deviations of Final Grade Comparing Different Class Times for fall Classes.

Class time	*n*	*M*	*SD*
8am	153	2.09	1.24
9am	268	2.05	1.24
10am	198	1.51	1.25
11am	60	1.41	1.31
12 noon	222	1.92	1.28
1pm	215	1.75	1.21
2pm	612	1.93	1.18
3pm	137	1.90	1.24
4pm	137	1.83	1.21

Table 4.6

Percentage Fail and Percentage Fail and "D" Rates for Spring Semester.

Spring	8 am	9 am	10 am	11 am	12 noon	1 pm	Large 2 pm class	Small 2 pm class	3 pm	4 pm*
Average %F	29.62	25.14	20.19	28.48	28.81	21.47	27.98	30.32	31.86	45.45
Weighted Average %F	29.73	25.21	18.18	28.9	27.07	21.43	29.06	30.61	30.89	45.45
Range %F	5.91	22.15	23.33	14.72	32.37	16.52	7.19	20.05	45.47	0
Average %DF	41.98	37.02	35.94	40.33	45.22	31.14	43.85	44.97	39.95	72.73
Weighted Average %DF	41.89	36.97	33.77	40.3	43.61	31.25	45.3	46.94	39.02	72.73
Range %DF	5.54	31.84	26.67	22.75	53.81	21.43	9.66	38.45	49.28	0

* This represents data from only one class.

The number of students who drop the course was considered for the Fall 2011 semester only because the data for the Fall 2009 and Fall 2010 have been affected by the intervention course that was run in those semesters. Again, the ten a.m. class stands out as having the highest drop rate (23.68%), but curiously, the nine a.m. class also has a high rate (21.79%) (See Table 4.8.). Detailed information about the students who dropped MATH 160 in Fall 2011 was not available so no common factors can be isolated.

Table 4.7.
Percentages of Intra-University and Repeat Students by Year and Time of Class for Fall.

	8 am	9 am	10 am	12 noon	1 pm	Large 2 pm class	Small 2 pm class	3 pm	4 pm
Fall 2009									
# in class	32	75	29	60	34	105	23	30	26
# IU	5	7	12	17	12	21	8	6	8
% IU	15.68	9.33	41.38	28.33	35.29	20	34.78	20	30.76
# Repeating	3	2	5	5	6	7	3	0	0
% Repeating	9.38	2.67	17.24	8.33	17.65	6.67	13.04	0	0
# Both	0	1	4	4	2	3	2	0	0
% Both	0	1.33	13.79	6.67	5.88	2.86	8.7	0	0
Fall 2010									
# in class	33	71	27	46	58*	109	38	25	34
# IU	7	14	10	10	17	15	8	4	9
% IU	21.21	19.72	37.04	21.74	29.31	13.76	21.05	16	55.88
# Repeating	0	5	7	4	7	3	2	0	1
% Repeating	0	7.04	25.93	8.7	12.07	2.75	5.26	0	2.94
# Both	0	0	4	1	4	0	1	0	0
% Both	0	0	14.81	2.17	6.69	0	2.63	0	0
Fall 2011									
# in class	30	61	26	53	62*	57	58*	21	20
# IU	3	8	14	16	14	11	13	4	5
% IU	10	13.11	53.85	30.19	22.58	19.3	22.41	19.05	25
# Repeating	0	5	7	7	6	2	3	1	1
% Repeating	0	8.2	26.92	13.21	9.68	3.5	5.17	4.76	5
# Both	0	2	4	2	4	1	2	1	1
% Both	0	3.28	15.38	3.77	6.45	1.75	3.45	4.76	5

* Data from two small classes represented here.

Table 4.8.
Percentage of Students Dropping MATH 160 by Time of Day of Class in Fall 2011.

Fall 2011	8 am	9 am	10 am	12 noon	1 pm*	Large 2 pm	Small 2 pm*	3 pm	4 pm
# in class who took exam 1	35	78	35	59	69	65	67	24	23
# in class who do not have a final grade recorded	5	17	9	6	7	8	9	3	3
% Dropped	16.67	21.79	23.68	10.17	10.14	12.31	13.43	12.5	13.04

* Data represents two classes

Redoing the correlation statistics, in light of the possible affect a student's repeat status might have, indicated the data for students studying MATH 160 for the first time in the fall had a medium to large strength correlation between CCHE index score to the student's final grade (r =

.45), as well as the aggregate PACe placement score to the student's final grade (r = .47) according to Cohen (1988). Whereas, for a student repeating MATH 160 in the spring, neither of these variables were statistically correlated to the student's final score.

The above analysis lends support to exploring in phase two several attributes and variables that might be used in estimating a student's likelihood of success in MATH 160:

- The semester the student is enrolled.
- If the student is repeating MATH 160.
- CCHE index score.
- Raw aggregate PACe placement score.
- The college the student is attached to.
- The time of day the student elects to attend the course.

Further analysis is required to identify why certain students are failing more than one course.

Phase Two Results

Research question two: Are there combinations of variables that can predict if a student will succeed, or fail, in MATH 160?

This question was broken into sub-questions and will be discussed here according to each sub-question.

a) Which variables, identified in phase one, are statistically significantly associated to success in MATH 160?

In order to answer this question, CCHE index score, ACT Math score, ACT combined score, SAT Math, SAT composite, aggregate PACe placement score, and time of day class taken were tested for correlation to the final grade using the historical data (Fall 2007 – Fall 2011). All the above were statistically significantly correlated to final grade at the $p < 0.01$ level, except time of day, Initially, the CCHE index score ($r = .39$, $r^2 = .15$, $n = 2{,}402$) and the aggregate PACe placement score ($r = .38$, $r^2 = .14$, $n = 2{,}296$) had the strongest correlations; both correlations having medium strength according to Cohen (1988). However, due to the findings in phase one, the data were separated into fall and spring and then reanalyzed.

For fall semesters, all correlations were statistically significant at the $p < 0.01$ level, again with the CCHE index score ($n = 1668$, $r = .45$, $r^2 = .20$) and the aggregate PACe placement score ($n = 1500$, $r = .47$, $r^2 = .22$) having medium to large strength correlation to final grade according to Cohen (1988). For spring semesters: all correlations were statistically significant at the $p <$ 0.01 level, again with the CCHE index score ($n = 659$, $r = .20$, $r^2 = .04$) and the aggregate PACe placement score ($n = 693$, $r = .21$, $r^2 = .04$) having the strongest correlations, but the strength dropped to small to medium according to Cohen (1988). It is known that the spring cohort contain many students who are repeating the course, so correlation tests were repeated, this time including the students status as a "repeater" taken into account. For the spring cohort, although CCHE index scores ($n = 493$, $r = .24$, $r^2 = .06$) and aggregate PACe placement score ($n = 511$, $r = .25$, $r^2 = .06$) were statistically significant correlations at the $p < 0.01$ level for those students not repeating, these variables were not statistically significantly correlated for those spring cohort students who were repeating (CCHE: $n = 166$, $r = .05$, $r^2 = .00$ and aggregate PACe placement score: $n = 182$, $r = .12$, $r^2 = .01$).

Multiple regression was conducted to determine the best linear combination of CCHE, aggregate PACe placement scores, what semester MATH 160 was taken, and repeat status for predicting final grades. For fall students who were not repeating, a combination of CCHE index and the aggregate PACe placement score yielded the best results ($R = .54$, $R^2 = .30$, $p < 0.001$). This group would best represent a freshman intake into this course. For fall students repeating this course, the correlation between the two predictor variables dropped the need for the second variable (aggregate PACe placement score yielded $r = .39$, $r^2 = .15$, $n = 99$, $p < .001$). For spring students who were not repeating, again, a combination of CCHE indexes scores and the aggregate PACe placement score yielded the best results ($R = .30$, $R^2 = .09$, $p < 0.01$), but not nearly as strong as for the fall cohort. This model was not statistically significant for the spring students who were repeating the course.

b) What percentage of the group who failed the first mid-term MATH 160 examination was predicted to fail based upon predictor variables? Of those students advised to take the intervention course was their success rate improved?

Before the Fall 2012 semester began students were advised to take either MATH 160 or an intervention course. The student was still responsible for deciding which course to enroll in. Those advised to take the intervention course would be predicted to make up a significant portion of the forty percent that fail the MATH 160 course in the fall semester. However there may be students who choose this course for other reasons.

As the mid-term examinations for MATH 160 are different from the intervention course, an exact comparison cannot be made. However, it is worth determining if these students are passing at all. The expectation is that twenty percent of the students who would have enrolled in MATH 160 enrolled in the intervention course instead. Hence twenty percent will still be predicted to fail MATH 160.

The following table (Table 4.9) reports the total number of students who passed and failed the first mid-term examination in MATH 160 and intervention course, as well as the results for students who should have taken the intervention course but chose to do MATH 160, and those who chose to do the intervention and would have been advised to take MATH 160.

Table 4.9.
First Mid-Term Examination Results in Terms of Pass/Fail.

	Pass Exam 1	**Fail Exam 1**	**Total Exam 1**	**% Pass**	**% Fail**
Took MATH 160	310	119	429	72.26	27.74
Took Intervention course	35	49	84	41.67	58.33
Should have taken MATH 160 and took intervention course	18	6	24	75	25
Would be advised to do intervention course and did MATH 160	59	34	93	63.44	36.56
Would be advised to do intervention course and did.	5	27	32	15.63	84.37

c) Which, if any, of the subscales of the Motivated Strategies for Learning Questionnaire (MSLQ) are statistically associated with success in MATH 160?

The pilot run in Spring 2012 in MATH 160 of the full MSLQ indicated the subscales of interest were the motivation subscales: control beliefs, test anxiety, self efficacy, and the study subscales: organization, time and study environment, effort regulation, rehearsal, elaboration, and help seeking. A pruned version of the MSLQ was then run against six sections of MATH 160 in Fall 2012 (n = 244 out of the total 429). Test anxiety and self-efficacy were correlated to the first mid-term examination score (n = 173, $p < .001$) as well as control beliefs, organization, effort regulation, and rehearsal (n = 173, $p < .05$). (See Table 4.10.)

Phase one also identified students who are repeating the course as being worthy of separate attention. Here, only two sub-constructs were statistically significant: test anxiety and effort regulation. (See Table 4.11.)

Table 4.10
Statistically Significant Correlations to the First Mid-Term Examination Scores in Fall 2012 to MSLQ Subscales as well as any Correlations to Each Other (n = 176).

	2.	**3.**	**4.**	**5.**	**6.**	**7.**
1. Exam1	-.37**	.34**	-.22**	.19*	.15*	-.16*
2. Test Anxiety		-.42**	.15	-10	-.19*	.23**
3. Self Efficacy			-.05	.64**	.38**	-.06
4. Organization				-.07	.20*	.64**
5. Control beliefs					.19*	-.08
6. Effort Regulation						-.06
7. Rehearsal						

** $p < .001$, * $p < .05$

Table 4.11.
Statistically Significant Correlations to the First Mid-Term Examination Scores for MATH 160 Repeaters.

	Test Anxiety	**Effort Regulation**
Exam 1 (n= 21)	-.57*	.54*
Test anxiety		-.49

* $p < .05$

Multiple regression was conducted on the Fall 2012 data to determine the best linear combination of CCHE, aggregate PACe placement scores, test anxiety, and self-efficacy for predicting the first mid-term examination results. The means, standard deviations, and intercorrelations can be found in Table 4.12. As CCHE index score and aggregate PACe placement scores are correlated ($r = .45$, $n = 168$) having both in the model did not add anything.

Therefore, as the aggregate PACe placement scores had the higher correlation value to the first mid-term examination scores, CCHE index score was removed from the model. The resulting model was analyzed and was statistically significantly correlated ($p < .001$, $F = 21.27$, $R = .58$, $R^2 = .34$) which is larger than typical according to Cohen (1988). The beta weights represented in Table 4.13 suggest that the PACe placement scores contribute most to predicting first mid-term examination results, and that test anxiety and self-efficacy for learning and performance also contribute to this prediction.

Table 4.12
Means, Standard Deviations, and Intercorrelations to First Mid-Term Examination Results and Predictor Variables.

Variables	M	SD	1	2	3
Exam 1 Score	63.56	18.51	$.47^{**}$	$-.37^{**}$	$.34^{**}$
Predictor Variable					
1. PACe placement score	30.73	9.62	-	-.12	$.21^{*}$
2. Test Anxiety	17.84	6.32		-	-.42
3. Self Efficacy	32.01	8.50			-

$^{*}p < .05$; $^{**}p < .01$

Table 4.13
Simultaneous Multiple Regression Analysis Summary for Aggregate PACe Placement Score, Test Anxiety, and Self-Efficacy Predicting the First Mid-Term Examination Results.

Variables	*B*	*SEB*	*β*
PACe placement score	.79	.14	$.41^{**}$
Test Anxiety	-.80	.26	$-.25^{**}$
Self Efficacy	.43	.21	$.16^{*}$
Constant	39.95	10.67	

Note. $R^2 = .34$; $F(3,124) = 21.27$, $p < .001$
$^{*}p < .05$; $^{**}p < .01$

d) Can a student's results in the first MATH160 mid-term examination course be predicted from a combination of predictor variables as identified above?

As the historical analysis indicated, there might be a difference between the results of students who are repeating MATH 160 and those who are taking the course for the first time, a t-test was conducted on the Fall 2012 data comparing these two groups' results for the first mid-term examination. There was no statistically significant difference between the two groups at the $p < .05$ level. ($n_R = 35$, $M_R = 65.57$, $SD_R = 16.04$, $n_{nR} = 209$, $M_{nR} = 63.23$, $SD_{nR} = 18.91$). The data were not split for further analysis.

Logistic regression was conducted on the Fall 2012 data to assess if any combination of the four predictors (CCHE, aggregate PACe placement score, test anxiety, and self-efficacy), could significantly predict if a student passed the first mid-term examination or not. A model using aggregate PACe placement scores, test anxiety and self-efficacy managed to predict 38.7% of those who failed and 89.7% of those who passed (CCHE index did not add to the model) ($X^2 = 30.70$, $df = 3$, $N = 128$, $p < .001$) Table 4.14 presents the odds ratios, which suggests that the odds of estimating correctly who passes MATH 160 improve by 12% if one knows the student's PACe placement score.

Table 4.14
Logistic Regression Predicting Who Will Pass and Who Will Fail MATH 160.

	B	***SE***	***Odds Ratio***	***p***
PACe placement score	.12	.03	1.12	.001
Test anxiety	-.13	.05	.88	.014
Self-efficacy	.01	.04	1.01	.819
Constant	.02	2.06	1.02	.994

Discriminant analysis was also considered to see if not only pass/fail could be determined, but also identify students likely to score a “D” on their first mid-term examination. Although some models were statistically significant, because the number range determining the grade of “D” is so small, no students were correctly predicted to get a score in the “D” range (43.8% correctly predicted to fail, 77.8% correctly predicted to pass, and 0% correctly predicted “D” using CCHE index score, test anxiety and self-efficacy in the best model).

Research Question three: What kind of association (if any) is there between students persisting with the MATH 160 course and the predictor variables identified previously combined with the student’s results from their first mid-term examination in MATH 160?

Note that in the past, the date where the student may drop the course without penalty came just after the first mid-term examination. It now comes after the second mid-term examination.

In order to answer this question the following sub-questions were examined:

a) Can a student withdrawing from the MATH 160 course be predicted from the student’s result (“D”, or “F”) in the first MATH 160 mid-term examination and other variables as predictors?

From the historical data, it is clear that the result in the first examination might have a strong effect upon a student’s decision to withdraw from MATH 160. (See Table 4.15.)

The Fall 2011 data were analyzed to determine if a student withdrawing, or persisting, was correlated to potential predictor variables. The Fall 2011 data were used because the Fall 2009 and Fall 2010 students had the option of swapping to an intervention course after the first mid-term examination, and hence, may be incorrectly identified as dropping out of MATH 160. For the Fall 2011 data, CCHE index scores, aggregate PACe placement score, and first mid-term examination scores were the only variables available. All of these variables were correlated to a student withdrawing, or persisting, with MATH 160 in Fall 2011 (See Table 4.16.)

Table 4.15
For Fall Students Who Withdrew From MATH 160, Where Data Are Available on First Mid-Term Examination Grade, College in Year MATH 160 Taken, And If They Persisted In the Same College In A Later Semester, or Have Left CSU Before Completing Their Degree.

Exam 1 results	**2009**			**2010**			**2011**		
Fail	39			53			46		
"D"	13			7			7		
"B", "C"	12			2			9		
Total who withdrew	64			64			62		
	Start	**Same Coll**	**Left CSU**	**Start**	**Same Coll**	**Left CSU**	**Start**	**Same Coll**	**Lelt CSU**
Engineering	30	3	11	29	5	7	17	8	2
Intra University	21	0	11	13	0	6	27	12	5
Natural Sciences	11	2	6	17	2	8	13	9	2
Other College	2	0	1	5	3	2	5	5	0

Multiple regression was also conducted. The means, standards deviations, and intercorrelations can be found in Table 4.16. These three variables significantly predicted a student withdrawing ($F(2,382) = 30.48$, $p < .001$), with first mid-term examination score and aggregate PACe placement score variables significantly contributing to the prediction. The adjusted R squared value was .23. This indicates that 23% of the variance in a student's persistence was explained by the model. According to Cohen (1988) this is a moderate to large effect. The beta weights, presented in Table 4.17, suggest that the results in the first mid-term examination score contribute most to predicting a student's persistence in MATH 160.

Table 4.16

Means, Standard Deviations, and Intercorrelations for Student's Persistence and Predictor Variables (n = 385).

Variables	M	SD	1.	2.	3.
Student Persistence	.85	.36	$.46^{**}$	$.29^{**}$	$.34^{**}$
Predictor Variable					
1. Exam 1	66.65	19.82	-	$.44^{**}$	$.46^{**}$
2. CCHE	118.63	11.33		-	$.61^{**}$
3. PACe Placement Score	31.04	9.57			

$^{**}p < .01$

Table 4.17

Simultaneous Multiple Regression Analysis Summary for First Mid-Term Examination Percentage Score, CCHE Index Score, and Aggregate PACe Placement Score.

Variables	B	SEB	β
Exam 1 Percent	.007	.001	.38
CCHE	.001	.002	.05
PACe Placement Score	.005	.002	.13

Logistic regression was conducted to assess whether the three predictor variables (first mid-term examination percent score, aggregate PACe placement score, and CCHE index score), significantly predicted whether or not a student persisted with the MATH 160 course. As there is a strong correlation between the CCHE index score and the aggregate PACe placement score, a model was tested with all the predictor variables entered individually as well as a model using just the first mid-term examination score and either the CCHE index or aggregate PACe placement score. When all these predictor variables are considered together, they significantly predict a student's persistence in the MATH 160 course (χ^2 = 67.36, df = 3, n =304, p < .001). Table 4.17 presents the odds ratio. Although the overall ability to correctly predict if a student will persist or not was 89.1%, the ability to correctly predict that a student will withdraw was low (29.7%). The model using the first mid-term examination score and aggregate PACe placement score was also statistically significant but the ability to correctly predict that a student will withdraw was lower (29.7%). The model using the first mid-term examination score and CCHE index score was not statistically significant. (See Table 4.18.)

Table 4.18
Logistic Regression Predicting Who Will Persist With MATH 160. Data From Fall 2011.

Variable	***β***	***SE***	***Odds Ratio***	***p***
Exam 1 Percent	.06	.01	1.07	.001
CCHE Index	.02	.03	1.02	.423
PACe placement score	.06	.03	1.06	.040
Constant	-5.59	2.52	.00	.027

As it would be useful to be able to predict a student's persistence before the semester begins, logistic regression was conducted on Fall 2011 data using a combination of CCHE index and aggregate PACe placement scores. The only statistically significant models ($p < 0.001$) included aggregate PACe placement score, however, the ability to correctly predict if a student will withdraw was very low (4.4%).

As the analysis from phase one indicated that different colleges had different withdrawal percentages (the Intra University college, in particular, had high numbers), multiple regression was redone, this time separating the test by college. This test indicated both the aggregate PACe placement score, and the CCHE index score could be dropped from the model. The logistic regression model test for Intra University correctly predicted 34.5% (10/29) using only the first mid-term examination percentage score (n = 117) (See Table 4.19.)

Table 4.19.
Logistic Regression Predicting Who Will Persist With MATH 160. Data From Fall 2011. For Intra University only (N = 117).

Variable	***β***	***SE***	***Odds Ratio***	***p***
Exam 1 Percent	.06	.01	1.06	.000
Constant	-1.97	.69	.13	.004

As the first mid-term examination score is only known after four weeks of the semester, multiple regression was also redone by college, using just the CCHE index scores and aggregate PACe placement scores. Neither CCHE index score on its own, nor using the CCHE index score in combination with the aggregate PACe placement score, produced statistically significant models. The aggregate PACe placement score on its own did produce a statistically significant model with medium effect sizes according to Cohen (1988) ($R_{EG} = .26$, $R^2_{\mathrm{EG}} = .07$, $n_{EG} = 205$, $p_{EG} < .001$; $R_{IU} = .26$, $R^2_{IU} = .07$, $n_{IU} = 62$, $p_{IU} < .05$; $R_{NS} = .31$, $R^2_{NS} = .10$, $n_{NS} = 49$, $p_{NS} < .05$). However, logistic regression has not been reported as using only the aggregate PACe placement score as a predictor variable reduced the data for analysis to the point where the number of students who withdrew from each college was less than twenty cases per college, and hence, not statistically valid (Leech, Barrett, Caplovitz, & Morgan, 2012).

b) Can a student walking away from the MATH 160 course be predicted from the student's results ("D", or "F") in the first MATH 160 mid-term examination and other variables as predictors?

For fall 2012, students were considered to have walked away from MATH 160 if they attended the first mid-term examination but failed to attend the second or third mid-term examination, or failed to attend the third examination. (See Table 4.20.) It should be noted that not all of these students formally withdrew. There were two common patterns for the students who did not attend the third mid-term examination: 14 out of 28 were attached to Intra University college; and 13 out of 28 did not fill in the first background survey. Similar results were found for the final exam. The latter is noteworthy because the students were offered ten points towards their homework total for the week simply for filling in the survey, and these students chose not to do it.

Table 4.20

Number of Students Withdrawing From MATH 160 by Mid-Term Examination in Sections 1,2,3,6,9, and 10.

Fall 2012	**Total Number of students**	**Total Dropped**
Start of semester	248	
Took exam 1	243	4
Took exam 2	233	10
Took exam 3	216	32
Took final	208	40

Two students did very well in the first mid-term examination, but failed to show up to the third mid-term examination. This current study was not designed to get at the reasons why these students walked away.

Analysis of the historical data also highlighted the time of day may have an effect, so the Fall 2012 data were broken down by section, as well as college (see Table 4.21). Again, the ten a.m. class stands out as having a high number of students who did not show up to the third mid-term examination.

As the numbers were so small, no further statistical analysis was performed.

Table 4.21

Break down of fall 2012 sections 1, 2, 3, 6, 9, and 10 by Mid-Term Examination Attendance, Repeat Status, and College.

Time of Day	**8am**	**9am**	**10am**	**1pm**	**3pm**	**4pm**
Number who took exam 1	34	81	33	33	30	33
College						
Engineering	20	54	14	19	21	14
Intra University	6	14	7	8	4	9
Natural Sciences	5	9	9	5	2	8
Other	3	4	3	1	3	2
Number who are repeating	3	10	11	9	2	2
Total not attend exam 3	4	6	7	5	3	3
College						
Engineering	0	2	0	0	1	0
Intra University	3	3	3	2	2	1
Natural Sciences	0	1	3	2	0	2
Other	0	0	1	1	0	0
Number who are repeating	1	0	3	1	0	0

Research question four: How do the students perceive their experiences of MATH 160?

In order to answer this question, students who completed the MATH 160 course in the fall semesters of 2009, 2010, and 2011 were invited to an interview.

Some common questions that were asked in the individual interviews included:

- Did they chose a major and then CSU, or CSU and then the major they enrolled in?
- What was their understanding or the level of work required for the major they enrolled in? Are they remaining with their chosen major?
- What did they expect this mathematics course to entail? What was their expectation for studying this course? How did they study the course?
- If they failed the course, what lead to their decision to stay/drop?
- What would they change about the course?
- Knowing what they know now, if they could have given themselves advice before they started the course, what advice would they give?

Thirteen students attended interviews and twenty-seven students opted to fill in a questionnaire instead. (See Tables M 8 & M9, Appendix M for numbers and attributes of these students, as well as Appendix L for a copy of the survey questions.) The names of the students as they appear here are pseudonyms. The grade the students attained in MATH 160 and the number of times they attempted MATH 160 can be determined from their pseudonym. If the student has only one name then they attempted the course only once, and the first letter of their name is their letter grade for MATH 160. If the student has a name followed by a letter, they attempted the course twice, with the first letter of their name being their letter grade for their first attempt at MATH 160 and the following letter is their letter grade the second time. For example, Warren B attempted MATH 160 twice, the first time he withdrew and the second time his letter grade was "B".

Deductive coding

The interviews were recorded and transcribed into text. Once in this form, the text was coded using commercial software. The theoretical framework for this study is based upon student motivation and how that interrelates to their self-regulation of study behavior, therefore, this lens was also applied to the coding. Below are the results broken down by MSLQ motivation sub-constructs: value component and Expectancy component, as well as learning strategy sub-constructs: study strategies, time and study environment, and peer learning combined with help seeking.

Values Component

Generally, the interviewees who had mathematics as either a major or minor did value the course material and the way the course was structured:

> Warren B: I mean, it's not too bad of a class, I think it's pretty good how it's structured.

> Whitney C: I really can't offer any advice to those (MATH 160) instructors because I think that they did what they're supposed to do and can't really do anything more that can improve the class.

Those who were not Mathematics majors suggested more be done to give motivation as to why, say, they needed to know the epsilon-delta details of limits, detailed definitions and proofs:

> Alice: I mean, just speaking to your audience. Knowing what students are interested in. If you're talking to all Math majors your, that lecture is completely different than speaking to engineers. It should be at least. So really knowing your audience I think would be very, very helpful, well 'cause engineers I think, you know, we, we can suffer through the derivations, but we really need to know: What it's there for, you know; Why are we using this; What can it be used on?

> Bill: If I could give advice to the instructors I would probably say that it's important to understand, to present the information to the proper audience … your engineers are looking at it completely different, you know, we're using it as a tool to achieve something and the theory is kind of where I think my little section gets buried … I'd say if you can work on a way to present it to a broader audience and do it in pieces that can be easily digested I think that might help with the current crowd that's in.

This is not to say they did not appreciate it. Some of those now studying Engineering and Natural Sciences say they now appreciate the rigorous approach to MATH 160. Further, there were suggestions of perhaps going even further.

> Andrea: I wish the high schools would teach analysis too, do proof along the way. That would be nice.
>
> Burt: I'm taking MATH 317 right now and I suppose a lot of stuff we are going to be doing in there I feel like should find its way somehow into the lower level. There should be more time spent with deriving things.

However, one of the interviewees commented that his peers found the attention to detail not to their taste:

> Warren B: Everyone who wants to be an engineer thinks about, like 'I want to build something really cool,' or this and that, but you got to go to the details, and minor calculations to get to that point and they never think about the long-term goal. I think they are just thinking 'I hate Math. I don't want to do it. I'd rather build something. ' Right? But you have to do Math to build something. I just don't think they see it like that.

Those who did poorly in the course did not understand the point of all of the assessment. The labs in particular were seen as "busy work" and not integrated into the rest of the course.

> Doug: The labs seemed like a combination of 'This is busy work.', and then going to 'I don't know what's going on.'
>
> Fred D: I didn't see labs for a long time. We had our first test and I hadn't even got a Lab back yet. To me it was like, these are a waste of time. They're not used. If I can't understand how to do it, or get feedback then they're not, they're just keeping me busy. I don't like that.

Expectancy Component

The students who were interviewed all believed that they were capable of learning the material in the course if they put in the time and effort to try hard enough:

> Bill: … in that first exam I got crushed, and I think I got a 'D' on the first exam and I was, yeah, I don't even remember what the problem was… after that I just got really pissed and just buckled down and said "I don't care. I'm going to nail this. I'm going to get through this class. You know. This will not get in my way."

> Warren B: …the first time I went into it expecting 'Oh this will be a piece of cake'. I got good grades in high school without studying, so I kind of thought I could do the same here, but it's not true. … But the second time I was, like, 'OK. This is going to be hard. Study. Expect it to be hard.'

> Frazer F: Really, the problem the first time was all about me. I just wasn't trying hard enough. I didn't take the course seriously enough.

Many of those who attained an "A" or a "B" were also quite confident about achieving a good grade:

> Alice: So I've always been fairly strong in mathematics, and I think the added benefit of having seen it, some of it, before in high school was very beneficial.

Whereas those who failed, or had a low pass ("D"), although they did work hard, seemed to believe they were not in control of their destiny:

> Frazer F: Again, my mathematical foundations are pretty flawed. I didn't get the best mathematical teaching all the way up through high school, and so a lot of my stuff is incomplete, or not really the best way to do it, or just wrong for instance. So, while I might be able to, you know, do the derivative or something like that as soon as I, a rule is thrown at me like a log of a log, it stops me dead in my tracks.

> Survey response from a failed engineering student: Had the professor been able to explain how he wanted the work done and been more efficient at teaching the subject I think my grade would have been much better.

> Dan D: He (instructor) didn't have any notes and didn't really know what section we were on. We'd recover some of the things we did from the previous lesson and not get anything done that he needed to get for the webwork, or the homework or what ever done every day, and it was, it was really terrible. I mean he was, he didn't plan anything ahead,

> Dan D: I couldn't go (to class). It was more difficult to go to class 'cause it would confuse me more to enter the classroom, and to go over things he would teach, but I knew that the, from the understanding that I had previously wasn't enough for me to get though it.

> Dan D: I got a D! And I worked really, really hard, but I realize there is a little bit of competition, and relearning a new language you know or learning an old language like mathematics. It's complicated.

> Warren B: When you're a freshman, you're super intimidated by this stuff, I was at least, it's being thrown at you at a pretty fast rate, and you might not be able to cope.

Attitude Towards Mathematics.

There was a noticeable difference in the student's attitude towards mathematics and how they might study mathematics. Those who passed clearly liked the subject, and worked out why the emphasis was on a conceptual understanding of the material:

> Anne: I do like mathematics, and it's exciting to learn, you know, these ideas but I sort of, I don't know, I like my brain to be a little stretched. I like to understand why. I like the "why" if it. … Just because you don't understand it the first time you hear it, it doesn't mean you can't understand it. You just need to keep working with it and be persistent.

> Frank A: It's not just numbers anymore. There's also actual, there's a language involved with it. You're putting more words to what you are doing now and that, I think, gets a lot of people in that respect. It's not just, yeah, it's not just numbers anymore. You are actually having to, you know, say what's going on.

> Burt: When I went to primary education, middle school, high school, I hated math. I wanted to have nothing to do with mathematics. … A couple of years ago I started thinking about the universe and physics and decided that if I wanted to understand more I had to have a good background in mathematics. And so, when I started approaching it with interest, and when I started approaching studying math in general as something that, that I cared about, something I wanted to understand, I wanted to see into it more deeply, I feel like that itself is like the core of like enabling somebody to succeed in a course.

> Alice: I think at that point in time in my collegiate career I was, kind of, I was pretty cynical about the, you know, the proofs and the derivations. I was like "Let's get to the end of it". But at this point, I really appreciate the derivations. Well, sometimes they're hard to, you know, to understand and to get through them; it really, really is helpful in your final understanding.

Those who did not pass, or did not pass well, were not always enamored with how the course was taught and graded:

> Whitney C: MATH 160 was geared towards engineers and physics kind of examples. That just went over my head.

> Frazer F: To be honest, it was more learning about how to take the course. As far as the Math was concerned a lot of us were, you know, getting better on that, but we, our grades wouldn't reflect it necessarily.

> Fred D: I wasn't good at the conceptual stuff. I didn't get a lot out of the lectures. I did better modeling examples, finding something that was similar to the problem I'm doing and learning that way. You know it's hard to find good examples, especially in the textbook.

There were also repeated references to MATH 160 being one of the 'weed-out' classes:

> Warren B: I was doing, like, Chem and Physics. A lot of what seemed to be weed out classes.
>
> Fred D: That semester it was, because it was my first semester here, and I'd been placed in what I call, you know, at least three what they call 'weed-out' classes, the term I kind of found out later to know as I got in.
>
> Anne: Because many people have told me in the past that these big freshmen courses that are hard, like Calculus and Physics and Chemistry, are 'weed-out' courses. They're to get students out of the, you know, math or engineering or science majors who can't kind of 'handle it'.

Study Strategies

All of the students interviewed were using standard studying techniques, at least once they focused their attention on studying the course. Successful students, however, used a broader range of resources:

> Burt: I had a lot of online resources. I had Khan Academy that I used a lot. MIT open courseware I used a lot.
>
> Bill: Conceptually, I had a pretty good idea of what we were covering on a lot of things, so most of what I did was just do problems over and over. I'd find just similar problems and solution keys online and just work through problems and work through problems.
>
> Bernice: I did practice problems on my own. So that was how I studied.
>
> Warren B: The second time around I would sit down, I just sat down and I just worked problems in my free time. I probably did close to every practice problem in that book, 'cause the more you practice the more you start to think about it in your free time.
>
> Anne: …like my mind wasn't used to translating basic ideas into this kind of weird math language, and so definitely I remember very clearly, like, being at my kids football game, and just like thinking, and being like "What?" looking at stuff, and like being, like, "How does this make sense?", and just trying to figure it out, and just taking several days, and like thinking about it as I fall asleep at night, and then finally it just starts clicking.

Time and Study Environment

Most of the interviewees found the course took a significant amount of time and effort. The difference between those who were successful in the course and those who were not was in how that time was used:

> Warren B: The first test that came around I thought I could study for it like you study in high school, which is minimal, … (the second time around) I'd put ten to twenty hours in per test on top of just normal what you'd study just to do the homework and stuff like that. So, a lot more time.

> Frazer F: Well the first time through, before I'd given up, what was wrong with my approach was I just didn't put in enough time and effort, I guess. … Really the problem the first time was all about me. I just wasn't trying hard enough. I didn't take the course seriously enough.

> Doug: I would say that having to push so hard in the class prepped me for doing better. Just for the time commitment, not necessarily for the methods, but just having to sit down and do the work, even if whether I was or wasn't in the mood to do it, 'cause it was such a necessity with 160. I mean, if you didn't do something for two days it was bad, you know.

> Bill: Well, it was difficult. I can tell you that. … I was pretty used to working freakish hours and being driven, probably beyond what is healthy, so I wasn't a stranger to just buckling down and spending a lot of hours just doing the work. So from that stand point, it wasn't too intimidating.

> Survey response from a successful engineering student: I recall just putting my head down, so to speak, and working my butt off.

Peer Learning and Help Seeking

All of those interviewed knew when they needed help. The differences appeared in their ability to find and utilize appropriate help. Those who were successful in the course were able to find appropriate help when they needed it. Those who were not were hampered by time constraints, not knowing how to best use the resources they had at hand, or by being very fixed in the kind of assistance they would accept:

> Fred D: I finally went up to the teacher … and I said "Is there any way I could meet with you". And she's like, "Oh yeah. Just come to office hours." I'm like "I don't understand, like, why can't I just meet you in your office and talk?", that's what I was accustomed to. And instead you go to a room with a whole bunch of people, and like this is 'office

> hours'. Didn't make sense. So I did go. … Couldn't get the one-on-one help you wanted, and so it was frustrating. So, like this isn't really benefitting me 'cause I needed help now. I couldn't sit there and wait a long time. I was stuck and, and they want to lead you to the answer.

Curiously, many of the students interviewed, both successful and unsuccessful, shunned group work:

> Alice: I prefer to study on my own.

> Andrea: I'm more of a solo studier.

> Bill: I'm a little bit more of a lone wolf. I work in groups, but especially at that time of my personal life being absolute chaos, I had a fuse about that long. So I just wanted to be left alone and just buckle down and do my own work, be accountable to myself and that's it.

> Frank A: I admit I kind of distanced myself from the rest of the class. That's just kind of how I work best. I'm a very independent learner in that respect.

> Whitney C: I tried to (work with a study group) but it didn't just work out. I don't know, people weren't as motivated as I was to study, or else I went in with a problem where I was in a group with somebody who really got it and they didn't know how to teach what they got, so, you know, you couldn't slow him down.

> Fred D: I didn't really meet anybody that was like a study partner. It was, you know, I felt, it was kind of awkward, especially the first semester. I felt like, because I was so much older, and they're very young, and it was just like, OK I didn't really fit in there. So, you know, would have been nice but it was just not there. I never really met anybody to work with.

Inductive Coding

The interviews were then reanalyzed for elements that were missed by applying the deductive lens by using a thematic analysis (Riessman, 2008), whereby, common themes were identified in the interview and survey data.

Issues for Non-Traditional Versus Traditional Students

Nearly half of the students who volunteered to be interviewed were non-traditional students. Some of them were returning to study after quite a long break.

> Dan D: It had been about ten years since I had been in the classroom so it was extraordinary for me to come all the way in and then just start at Calculus, Physics, Chemistry in the very first semester. But I felt up to the task.
>
> Doug: Coming in cold after twenty years…

They did not make the decision to take up post-secondary education lightly. They all knew that they needed to brush up on their Algebra and Trigonometric skills and did so:

> Doug: Probably spent, I would say realistically, more than a 100 hours of prep time brushing up Algebra and doing that for the class.
>
> Fred D: I had, since I'd taken time off from previous school, I had to go back and, sort of, refresh my college algebra and trig, so first semester, before I came to CSU, I went to Front Range, retook college algebra, retook trig and did really well in those.

They chose CSU because it was convenient, offered the degree program they were interested in, and for some who had been long time Colorado residents, they were proud to be accepted into a degree program by CSU.

> Fred D: I've grown up in Northern Colorado pretty much all of my life so it was my plan, after I graduated from junior college, to come here, but other things happened and I took a lot of time off and decided that I always wanted to go to CSU because I just like CSU, I like Fort Collins so if I were to go back to school that's where I was going to go, so that was the main reason I came here.

Their circumstances meant they did not always have the same access to resources available to traditional students.

> Fred D: Unfortunately, I couldn't go to the evening where they had this tutoring at 5 to 10 because I needed to be home so their, their help here didn't really work with me as an adult learner.
>
> Fred D: So, but I guess I felt like, well this place is geared for kids who live in the dorms and have nothing to do at night, and that doesn't really consider the adult learners.
>
> Further, two of them struggled to balance study, work and family responsibilities.
>
> Doug: I had a domestic issue with time that came about, and so that started to restrict my time at school.

> Fred D: I was in class, was almost twenty hours, and then you add in the calculated homework time you're supposed to do, and I'm an adult learner, I already have a family, I had a new baby, and I had to get home at night to help out 'cause that was just kind of the way it was, and I wasn't prepared for the workload for the amount of credits.

The non-traditional students who failed, or did not get the grade they required, were still quite persistent. They had not taken the decision to return to study lightly, and so they sought to address what they thought were the impediments to their success.

> Frank A: First time I did it was actually just doing problems; was actually just crunching problems, just working through problems every time without actually understanding any theory but actually just looking at, just looking at the mechanics saying, 'OK this happens, you do this', not actually looking at, you know, why it happens. Once I understood why it happens, and that's where it happened – I took it the second time – I understood better why it worked the way it did, that's when it really became a lot easier and I'm able to do it really well.

> Fred D: Well, I had failed both Chemistry and Calculus, and that was mostly trying to salvage the Mineralogy, so, I was like, I'm just going to repeat/delete these both right now and get them done. 'Cause I, I didn't want those 'F's there, well for GPA reasons you got to get that and, so I felt like 'well they're going to be as fresh as they will be in my mind if I do it now.

> Dan D: I felt that I was able to look at some of the things that, that I thought maybe, you know, were causing me problems, that maybe taking it early in the morning, may be I needed a change in my note taking.

Quality Control of Instruction

Several of the students interviewed, and one of the survey respondents, strongly suggested that the MATH 160 instructors receive more supervision and feedback. Notably, the students who had also taken Chemistry suggested that mid-term student feedback be taken, as there are courses in the Chemistry department that run this with apparent success:

> Dan D: I think specifically, I think just about all of them, except the coordinator are TA's. They're all TA's and some of them are doing a great job. And some of them, it's their first time and can be floundering quite poorly. Or I think that having a midterm evaluation would benefit the instructor, benefit the Department, and would benefit the students.

Alice: The ranks of the mathematics instructors go from the very best to the very worst here at CSU in my personal experiences, and so some, in some way we need to bring that to more, to consensus and a more level, you know, level of expertise. I've had some professors that don't even turn around to look for questions and hands the whole time they're staring at the notes from the course coordinator and writing it up on the board, which doesn't work for anybody let's be honest, and so maybe in addition to student evaluations maybe even having the course coordinator come in and sit in on a few lectures that they're giving – unannounced even. Just coming in and just, you know, just kind of evaluating where that professor is at.

Doug: I heard very consistent feedback off campus around Fort Collins "Oh yeah, I've heard the Math Department over there is really bad", as in not teaching well. They know the material but they don't teach well. … I had an advisor tell me to take my math somewhere else and bring it in, and that I would end up having to relearn some of it because it wasn't being done well on campus. So there's, you know, the department has a reputation off and on campus, and different departments have very consistently said that, and it's not about the caliber of people, and it's not about understanding the material, its about the way it is taught.

Us versus Them

Of the thirteen students interviewed, five are now studying engineering majors. When interviewing these students, there was a strong impression these students saw themselves as a group apart.

Alice: I think specifically for engineers, so mathematics deals in the realm of all possibilities essentially, and you go from nil to infinity, and infinity for us is ridiculous. It's an absurd concept, and so for engineers are so practical that we really just want to get to what the tool really is.

Bill: …the mathematics majors are going to be very pretty naturally inclined to doing the academic side … and your engineers are looking at it completely different, you know, we're using it as a tool to achieve something.

As highlighted earlier, both the above students thought the course should give more motivation and examples aimed at engineers, especially as such a large portion of the cohort each semester taking MATH 160 are engineering students or students intending to take engineering. Whereas others, such as Whitney C, found there were too many engineering and physics examples that "went right over my head". There is an emerging theme that MATH 160 is perhaps aimed at too diverse an audience, and some who are advised to take it are not perhaps suited to it's current form.

> Fred D: (there were) two Math routes … that you could do: two Calculus Biology, or three Calculus for Engineers and Physical Sciences. So I asked the advisor 'What's the difference?' I was confused as to why we had these different options and she said like, 'Well if you ever want to go down the other route you would have, it basically gave you more options'. So I'm like, 'Oh OK. I'm all about options at this point.' I want to keep, you know, as many doors open, so I decided to take that route.

Phase Three Results

Research question five: What results emerge from comparing the quantitative data predicting a student's success, or failure, in MATH 160 with the qualitative analysis of the student interviews?

In the light of the analysis of the interview data, the different datasets were reanalyzed, taking into account student's prior experience of mathematics, as well as identifying if they were 'traditional' or 'non-traditional'.

Prior experience with mathematics.

As highlighted in the student interviews, a student's prior experience with mathematics may also have effect on their performance in future courses in mathematics. This also emerged in pilot work done in Fall 2010 and Fall 2011 to develop a mathematics background survey. The survey was run in the second week of the semester in six of the ten sections of the Fall 2012 MATH 160 cohort and the data collected using on line software (*n* = 248). One hundred and forty-nine students completed this mathematics background survey. Of this 100, of these students are also doing either Chemistry and/or Physics at the same time. The top eight qualities these students believe were required to be successful in mathematics, as well as which of these qualities they believed they had, are summarized in Table 4.22.

Table 4.22
Summary of the Top Eight Qualities Students Believe are Required to Study Mathematics.

Qualities	**Required (frequency)**	**Have (frequency)**
Dedication	35	31
Determination	33	25
Patience	24	16
Perseverance/Persistence	22	16
Work Ethic	19	18
Ability/ Intelligence	19	12
Motivation	17	12
Focus	16	10

The student scores from the mathematics background survey were compared to the student's first mid-term examination score. The following were statistically significantly correlated to the first mid-term examination score: prior calculus experience (n = 148, r = .20, p < .05), perception of quality of mathematics teaching experienced in high school (n = 148, r = .18, p < .05), how easy a student believes mathematics is (n = 148, r = -.17, p < .05), and average number of hours spent studying mathematics above and beyond homework and preparation for a test (n = 145, r = -.17, p < .05) (See Table 4.23).

Table 4.23
Means, Standard Deviations, and Intercorrelations for First Mid-Term Examination Results and Predictor Variables.

Variables	**M**	**SD**	**1**	**2**	**3**	**4.**
Exam 1 Score	63.56	18.51	$.47^{**}$	$-.37^{**}$	$.34^{**}$	$.18^{*}$
Predictor Variable						
6. PACe Placement	30.73	9.62	-	-.12	.17	-.00
2. Test Anxiety	17.84	6.32		-	$-.42^{**}$	-.09
3. Self Efficacy	32.01	8.50			-	-.05
4. Quality of HS						-

$^{*}p < .05$; $^{**}p < .01$

Multiple regression was conducted to determine the best linear combination of aggregate PACe placement scores, test anxiety, self-efficacy, as well as the above data for predicting results of the first mid-term examination. The resulting model was analyzed and the model with the strongest statistically significantly result included aggregate PACe placement scores, test anxiety, self-efficacy, the perception of quality of mathematics teaching experienced in high school, and organization (n = 101, p < .05, R = .63, R^2 = .40). This R-value is larger than typical. (See Table 4.24.)

Table 4.24
Hierarchical Multiple Regression Analysis Summary for Aggregate PACe Placement Score, Test Anxiety, Self-Efficacy, and Perceived Quality of Mathematics Education in High School for Predicting First Mid-Term Examination Results.

Variables	*B*	*SEB*	*β*	R^2	ΔR^2
Step 1				.34	.34
PACe Placement	.79	.16	.41**		
Test Anxiety	-.81	.28	-.25*		
Self Efficacy	.43	.24	.16		
Constant	39.95	11.71			
Step 2				.37	.03
PACe Placement	.79	.15	.41**		
Test Anxiety	-.73	.28	-.23**		
Self Efficacy	.48	.23	.18*		
Quality of HS	3.62	1.66	.17*		
Constant	26.57	13.02			
Step 3				.40	.03
PACe Placement	.78	.15	.41**		
Test Anxiety	-.65	.28	-.20*		
Self Efficacy	.49	.23	.19*		
Quality of HS	3.81	1.63	.18*		
Organization	-.88	.41	-.17*		
Constant	36.74	13.67			

Note. R^2 = .37; F(5,101) = 13.26, p < .001
*p < .05; **p < .01

Logistic regression was conducted to assess whether the predictor variables (aggregate PACe placement scores, Test Anxiety, Self-efficacy, perceived quality of schooling, and organization), significantly predicted whether or not a student passes or fails the first mid-term examination. When all predictor variables are considered together, they significantly predict whether or not a student passes the first mid-term examination, ($\chi^2 = 21.12$, $df = 5$, $n = 80$, $p < .01$). However, the overall percentage correctly predicted was higher using only the first three variables (82.1% as opposed to 79.5%). But still, this model was only 33.3% correct in predicting a student to fail. Table 4.25 represents the odds ratios, which suggest that the odds of predicting correctly who passes MATH 160 improve by 18% if one knows the student's PACe placement score.

Table 4.25
Logistic Regression Predicting Whom Will Pass the First Mid-Term Examination.

Variable	***β***	***SE***	***Odds Ratio***	***p***
PACe Placement	.16	.05	1.18	.001
Test Anxiety	-.04	.08	.97	.654
Self-efficacy	.05	.05	1.05	.384
Quality of HS	.41	.40	1.50	.305
Organization	-.07	.12	.93	.522
Constant	-4.46	3.52	.01	.206

Non-traditional students.

Many of the students who volunteered to be interviewed identified themselves as being "non-traditional", that is, returning to study after taking time away from study. Their specific set of circumstances appeared to be worth following up, especially because those interviewed who did have to repeat the course were quite persistent. CSU does not specifically capture statistics on non-traditional students. The Registrar's Office was able to update the original data sent with an indicator of whether the student was over the age of twenty-three when they started MATH

160. This information was used to identify non-traditional students. After the identification data were encrypted again, the data for the non-traditional students were reanalyzed.

Although their numbers are small compared to the total of students in the course, the percentage of them who fail is a concern (see Table 4.26). In particular, approximately half of the non-traditional students who failed MATH160 also failed another course as well.

Table 4.26
Number of Non-Traditional Students in MATH 160 by Result.

Semester	# Non-traditional students	Pass	D	Fail	% F	%DF	Failed more courses
Fall 2007	20	11	2	7	35	45	2
Spring 2008	23	15	2	6	26	35	3
Fall 2008	13	3	1	5	38	46	3
Spring 2009	10	8	0	2	18	18	1
Fall 2009	26	19	1	6	23	27	1
Spring 2010	17	10	1	6	35	41	3
Fall 2010	26	15	5	6	23	42	2
Spring 2011	27	19	2	6	22	30	3
Fall 2011	36	21	2	12	33	39	7

Breaking this down by time of day that non-traditional students attend class highlights the fact that the eight a.m. class has high numbers of failures in this group (see Table 4.27). This fact is made even more severe when class size is taken into consideration: the eight a.m. classes only have 30 to 35 students compared to the two p.m. class that generally has 70 to 100 students.

For the Fall 2012 MATH 160 students in the sections under analysis, there were only twelve students that could be identified as "non-traditional". This number is far too small to produce any statistically significant results. A t-test was performed to compare the non-traditional student's results to the traditional student's results; the test found no statistically significant difference at the $p < .05$ level ($n_{nt} = 12$, $M_{nt} = 58.08$, $SD_{nt} = 25.58$, $n_t = 232$, $M_t =$

63.84, SD_t = 18.10). Therefore, it can only be noted here that the one variable that produced any correlation to the first mid-term examination was the MSLQ self-efficacy construct for the six non-traditional students who completed the reduced MSLQ questionnaire (n = 6, r = .83, r^2 = .68). As this effect is larger than typical if a larger pool of data were to become available then perhaps this could be pursued further.

Table 4.27
Number of Non-traditional Students in MATH 160 by Time of Day Fall 2007 – Fall 2011.

Time of day	**Total**	**Pass**	**D**	**Fail**
8 am	29	15	1	13
9 am	25	16	4	5
10 am	29	19	2	8
11 am	14	7	1	6
12 noon	30	21	2	7
1 pm	18	12	0	6
2 pm	34	23	4	8
3 pm	7	4	1	2
4 pm	9	7	1	1

CHAPTER V: DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS.

"I'd say that the 160 is probably the hardest course I've ever had in my life." Doug.

Summary

The purpose of this study was to better understand what common factors might exist for students who are part of a high failure/drop rate in MATH 160, and determine if there are changes possible to ameliorate the pass rate in this course. This chapter discusses the results of the research questions, and makes recommendations for future research. As the study design is mixed methods, these results will be discussed under theme headings.

Phase One.

In this phase, historical data were analyzed to try and identify any common characteristics of students who fail or withdraw from MATH 160. Analysis of the historical data (Fall 2007 – Fall 2011) indicated the CCHE index score and the aggregate PACe placement score were two variables that might be useful in predicting if a student will be successful in MATH 160. Further analysis showed the correlation of these variables to the student's final grade depended upon the semester the student took the course, as well as whether or not the student was repeating the course. The two scores were good predictors for fall students new to the course, but irrelevant for a student repeating MATH 160 in the spring.

Breaking up the data by college brought into focus the high fail rate of students attached to the Intra University college. If these students were aiming to enter engineering courses, they needed a "B" to pass MATH 160. Anecdotally, some of these students who are not on track for a

"B" walk away from the course to concentrate on other subjects, looking to repeat/delete MATH 160 and repeat it in another semester.

The data were also analyzed by section. The eight a.m. and nine a.m. sections in fall semesters have low fail rates and statistically significantly higher final grade averages than the ten a.m. and eleven a.m. classes. The only common characteristics of students taking the ten a.m. class that could be found were a higher percentage of students attached to the Intra University college, and a higher percentage of those repeating the class than the other times during the day.

Of those students who were failing MATH 160, there was a noticeable group that was failing more than one subject. The two other subjects that students regularly fail at the same time they attempt MATH 160 are General Chemistry 1, and Physics for Science and Engineering 1.

Phase Two.

In this phase various models were analyzed to determine if the variables from the first phase, as well as any other variables that might be gathered before or early on in a semester, can be used as predictors for student success in MATH 160. For the fall semesters, the best linear combination for predicting MATH 160 results used CCHE index score, aggregate PACe placement score, as well as MSLQ constructs of test anxiety and self-efficacy for learning and performance.

Several logistic regression models were tested. Although many had high success in predicting student success in MATH 160, the percentages of correctly predicted student failure were low. The models tested were far better at predicting success than failure.

Sadly, when it came to persistence, the best predictor was the results of the first mid-term examination. Logistic regression models tested were better at predicting persistence than withdrawal from the course. Although phase one indicated the college a student is attached should be included as a predictor variable, when doing the analysis for Fall 2011, the best model again included the first mid-term examination score, and not other data that would be known before the semester began.

For the qualitative part of phase two, former MATH 160 students were interviewed and surveyed. The following observations emerged.

Motivation.

A common belief amongst students interviewed was that the course could be satisfactorily passed if the student worked hard enough. Those who did well were generally confident in their mathematical skills, whereas, those who did not were quick to point out what external factor hampered their success. This links well to the results from the data collected from the MSLQ, whereby self-efficacy (positive) and test anxiety (negative) were statistically significantly correlated to students' results in the course.

A reference to MATH 160 being a "weed-out" course appeared a number of times. Those who referred to this defined the term as "weeding-out those who were not willing to work hard enough", which is interesting as these were often the students who were putting in enormous amounts of time and effort into the course and still not succeeding.

The engineering students recommended working on the motivation for the course by increasing the engineering examples, or at least showing where the theory might be used in the future. However, some non-engineering students were left cold by the current physics and engineering examples already given.

Learning strategies.

Almost all of the respondents to the survey and interviews indicated they spent a significant amount of time on the course. What varied between those who did well in the course and those who did not, was how that time was spent. Some of those with low grades knew they should not spend all of their time on MATH 160 just doing the assignments, however, that is exactly what they did to keep up with the assignment schedule of the course. Many who did well in the course did additional unassigned problems on top of the set course assignments. These extra problems were sourced from the course textbook, other calculus textbooks and online resources.

A surprising number of students interviewed avoided working with other students. This was true of the high achieving students as well as those with low grades, although the reasons were different.

Other emerging themes.

Nearly half of the students who agreed to be interviewed were non-traditional students. Some of these students did well, and others struggled. Their ability to survive seemed to depend on their ability to balance study, home responsibilities, and work commitments. There seemed to be variation in their ability to access appropriate assistance, as well as some non-traditional students who felt inhibited by working with younger students.

Another theme to emerge related to the low quality of instruction received both in high school and at CSU. This is consistent with the results in Seymour and Hewitt's (1997) study. (See Table 2.1.) The complaints were not only restricted to low achieving students, some of the "A" students were critical as well.

Phase Three.

For phase three, using some of the themes that emerged from the interviews, the Fall 2007 – Fall 2011 data and Fall 2012 data were reanalyzed. If non-traditional students were struggling in MATH 160, they were often struggling in their other subjects as well, and so were part of the group identified earlier who were failing more than one subject in the semester they failed MATH 160. Further, there is an identifiable contingent of non-traditional students that congregated in the eight a.m. class and were failing.

A model using aggregate PACe placement score, test anxiety, self-efficacy, the student's perception of the quality of mathematics teaching experienced in high school, and organization, to predict success in the first mid-term examination. Analyzing the Fall 2012 data, produced a larger to much larger than typical effect (n = 101, R = .63, R^2 = .40) according to Cohen (1988). However, logistic regression still showed the ability to predict failure is low. The best model used only aggregate PACe placement scores, test anxiety, and self-efficacy scores, but still only managed to correctly predict 33.3 perecent of those who failed.

Discussion

Using descriptive statistics has helped to identify groups of students who might struggle to either complete MATH 160 or attain a satisfactory grade. Firstly, it was clear that the fall semester cohorts, considered as a group, differed from the combined spring semester cohorts. A model using CCHE index score, aggregate PACe placement score and repeat status was a good predictor of success for the fall semester students who were not repeating, but not for students repeating in the spring semester. The difference could be due to the higher percentage of students who repeat in the spring. The fall cohort has the higher percentage of those students who are attempting MATH 160 for the first time. So trying to identify pockets of students who might benefit from an intervention, therefore circumventing the need to repeat in the spring semester, appeared worthwhile. Subsequent analysis focused on finding other attributes of students in the fall cohorts that could be used in a model. However, applying the various combinations found to a statistical model suffered from the small size of each group. The groups that emerged which could benefit from an appropriate intervention are: students attached to the Intra University college, non-traditional students, and those who choose to enroll in the ten a.m. class. These groups also overlap.

Intra University

As previously noted, most students attached to the Intra University college are required to get a “B” in MATH 160 in order to progress. In the Fall 2012 semester, half of those students who did show up to the first mid-term examination but did not show up to third mid-term examination, were Intra University students. Most of these students scored well below the required score for a “B” in the first mid-term examination. There is supporting evidence for the anecdotal observation that if such a student is not on track to get a “B”, rather than withdraw from the course, they stop working on the class and instead concentrate on the subjects they can get the grade they require. For MATH 160 they then take a “repeat/delete” option.

Two of the students interviewed were traditional Intra University students: one failed MATH 160 twice, and the other withdrew during his first attempt to avoid failing, and then achieved the requisite “B” the next time he attempted the course. Both students admitted they did not take studying for the course seriously enough the first time around. Each student was asked what advice they would give to themselves if they had the chance to talk to themselves before taking the course for the first time. Warren B’s response certainly gives an insight into what most might think the underlying problem is:

> Warren B: If I could go back in time I would say “Don’t mess around. College isn’t a joke. You have to work hard.” I feel like it is a full-time job and I treated it just like a hobby.

However, this is not the total picture. The other student, who failed the course twice, indicated that once he applied more time and effort, then his lack of background knowledge and understanding of what was wanted in the assessments hindered him more. This sentiment was echoed by some of the non-traditional students who were returning to study after an extended period of absence.

Table 4.15 highlighted the number of students who started in a particular major and then either changed majors or left CSU. The Intra University students are expected to change college as they either work out what major they want to pursue or gain entry into the major they originally wanted. What table 4.15 makes prominent is that around half of those Intra University students who dropped out of MATH 160 per semester left CSU completely. Those interviewed were all examples of persistent students. When asked why they persisted when others around them did not, consistent with Seymour’s (2002) study, they indicated their persistence was based on intrinsic interest in the major they were studying, rather than being intrinsically interested in the material covered by MATH 160 (or indeed mathematics). The following are two examples from students who took the class twice:

> Warren B: I don’t know why people do that (change majors after failing MATH 160). I’ve had friends that do it and I just, I don’t know, I think it’s kind of, they need to buck up, you know. It’s not like,… everyone gets slapped down every once in a while. But, yeah, I don’t know why people would change degree over one class.

> Whitney C: After my first time taking Calculus I watched so many of my peers completely change majors because of the calculus class, and maybe it was the right thing for them, but also I pitied them, and thought well “why are you limiting yourself so

> much? I mean it's just one class, you know, you can get through it. It's, sure, a lot of work now, but you can get through it.".

Warren B also commented that many of his peers lacked patience with the need to pay attention to detail. They wanted to "do" rather than plan in detail what to "do" (see Chapter Four). The MSLQ instrument measures intrinsic interest in the specific class where the instrument has been run. Seymour (2002) found students were more persistent if they were intrinsically interested in the major they were studying. In the Spring 2012 pilot run of MSLQ, the math majors were the only majors doing MATH 160 with a correlation between their intrinsic interest construct and their results in the mid-term examinations. As the number of mathematics majors in the Spring 2012 cohort (n = 6) was so small, this correlation is not reported. However, perhaps if this instrument were used again permission should be sought to take the questions relating to intrinsic interest and redirect them to the major being studied rather than the course being studied. This might improve the ability to predict those likely to withdraw.

Time of day discussion (Fall ten a.m. class).

The fall ten a.m. and eleven a.m. classes have more (by percentage) Intra University students than the other sections (see Table 4.7), however, these students do not always get low grades. Further, these classes have more (by percentage) students who are repeating MATH 160 than other sections (see Table 4.7), but again, these students do not always get low grades either. Why this class has a higher percentage fail rate than the other times the class is held may be due to the presence (or absence) of these students in the classroom. The Intra University students were discussed in the previous heading. The students who are repeating MATH 160 have seen the course before, and they may be less engaged in the class (Wood & Lynch, 2002). Their presence in the class in such high numbers may affect the learning environment of the rest of the class.

One of the instructors of this class did comment that students in his fall ten a.m. class seemed to not know each other outside of class (the students did not talk to each other much) and many of them seemed to be individual learners (D. Ortego, personal communication, 5th October 2012). Those who are repeating might not be in step with the cohort they started with, and the Intra University students may not have a group doing similar courses with a similar time-table. This may inhibit students of this class from forming steady study groups, but is not clear if this necessarily hampers the student's learning of the material at all.

Non-traditional students.

The eight a.m. class has a high proportion of non-traditional students who are failing (see Table 4.26). This may indicate the time this class is held is convenient for those who are still working a typical 9 a.m. to 5 p.m. work day, and so it is possible they are taking on too much by working and studying at the same time. Certainly Doug mentioned his study, and grade, were hampered by domestic conflicts over the amount of time he was spending on study and work. When looking for common factors of those who were failing more than one subject, non-traditional students were certainly an identifiable group. These students may need firm advice about what time commitment is required for post-secondary courses before they enroll for a semester. Taking fewer courses each semester may be better advice to this group as they work out their ability to balance home, work, and study commitments.

The non-traditional students interviewed who were successful were adept at working out ways to approach studying MATH 160 that suited their learning styles, as well as managed to find ways to fit the heavy time commitment into their existing work, or family, schedules. Those who were not successful, such as Fred D, were swamped quickly, at a loss as to how to utilize, or even find, the help they wanted, as well as not managing to balance their study and home schedule. According to Bill, the administration of CSU are aware non-traditional students need different support and are moving to address issues of child care and group support, however, although Fred D was aware of some of these services, he found they did not suit him.

Frank A, Dan D, and Fred D are non-traditional students who repeated MATH 160. All of them changed something about the way they approached the course the second time around. Frank A decided he needed to change from a purely problem solving approach, without understanding the theory, to working on fully understanding the concepts before attempting the assignments, an approach which worked very well for him. Dan D worked on improving his note taking so he had a more solid basis to study, but felt hampered by a disorganized instructor. Fred D decided he was best off doing it by himself and trying to pattern-match examples he found online, or in other calculus texts, to the questions in his assignments. He also found a tutor, which gave him the one-on-one assistance he wanted, however, despite Fred D's intentions, his sessions with his tutor largely focused upon completing assignments for the course. He mentioned "getting stuck". This seemed to happen frequently in both tests and homework, and he did not seem to have any mechanism for either getting unstuck, or moving on.

Fred D claimed he preferred the style of course delivery he had become accustomed to at Front Range Community College, where he claims the help outside of class was far more personalized. Honkimaki, Tynjala and Valkonen (2004) identified nineteen percent of students in their study reacted negatively to a change in style of course delivery, and Hockings (2009) claims there are students who will only take knowledge from their instructor, either of these observations could account for Fred D's reaction to the presentation of Calculus at CSU. When asked what advice he would give to himself if he had the chance to talk to himself before taking the course for the first time, Fred D responded:

> Fred D: To take it at Front Range. I've told everybody I've encountered. It's like, I wouldn't take it here. I'd go to a community college and take it and transfer 'cause I just was not impressed with the system of how it went and that's going twice and utilizing what help was out there.

Fred D mentioned that he could not get to the tutoring that was available between five and ten p.m. or the examination review sessions, and the assistance offered by the Adult Learners and Veterans Services on campus did not suit him. Perhaps he is correct, perhaps he should have completed the mathematics requirement of his degree at Front Range Community College, as he had become accustomed to the style of course delivery (assuming this remained similar for the Calculus course). As MATH 160 is a service course, it does cater to a large audience. Perhaps it should be admitted this course cannot cater to all audiences.

Motivation to Study MATH 160.

Two of the MSLQ motivation scales were correlated to the first mid-term examination score: self-efficacy for learning and performance (consistent with Robbins et al., 2004), and test anxiety. This agrees with some of the results of a study on academic self-handicapping in Psychology students by Thomas and Gadbois (2007), which included using both the MSLQ and SPQ instruments. In some sense, these two constructs measure similar things: self-efficacy for learning and performance, in part, is measuring a student's self-appraisal of their ability to master a task, meanwhile, test anxiety measures a student's self-appraisal of their ability to demonstrate they have mastered a task. A statistically significant correlation existed between these two components (see Table 4.10). It is quite alarming that test anxiety had such a high negative correlation to the first mid-term examination score (medium, or typical strength according to Cohen, 1988, see Table 5.1) and was one of the predictors of course success identified in phase two. Interestingly, in the Fall 2012 results, test anxiety has a correlation to rehearsal study strategies (which is linked with surface learning strategies), but not to elaboration, (which is linked to deep learning strategies); again this is consistent with the Thomas and Gadhois' (2007) study (See Table 5.1.). They suggested low achievers were students who lack confidence in their abilities and self-handicap by leaving study to the last minute, necessitating the use of surface learning techniques (Thomas & Gadhois, 2007). Most of those interviewed who did not achieve the grades they needed were not leaving their study to the last minute, however, they were not using the vast amounts of time they dedicated to MATH 160 effectively either. If they knew of better study techniques then, for whatever reasons, they did not apply them to MATH 160, or they believed solving problems by pattern matching is how mathematics is done.

> Fred D: I wasn't good at the conceptual stuff. I didn't get a lot out of the lectures. I did better modeling examples, finding something that was similar to the problem I'm doing and learning that way. You know it's hard to find good examples, especially in the textbook.

If a student is willing to invest a large amount of time studying calculus, then identifying those that are not using this time effectively, and directing them towards an appropriate intervention, might work to reduce the fail/drop rate. It is still not clear how this could be done before the semester begins. It might require using results from the first mid-term examination combined with self-reporting from the student. However, CSU has a system in place to contact students who are struggling, to guide them to online courses, and other interventions, and there is still a high fail/drop rate. Perhaps already doing badly in the first mid-term examination is reinforcement to these students to resist changing a study strategy that has worked for them in the past. A more direct intervention may be required.

Table 5.1
Table of Correlations to Test Anxiety from Fall 2012 Data.

	1.	**2.**	**3.**	**4.**	**5.**	**6.**
1.Test anxiety	-	.23**	.03	-.19*	.17*	-.37**
2. Rehearsal		-	.46**	.17*	.43**	-.16*
3. Elaboration			-	.31**	.39**	-.11
4. Effort Regulation				-	.65**	.15*
5. Time and Study Environment					-	.06
6. Exam 1						-

Study strategies used by MATH 160 students.

Group work.

As group work is central to study techniques such as Supplemental Instruction (Martin, Arendale, & Associates., 1992), those interviewed were asked their views on group work. As indicated in chapter four, half of them avoided group work, or at least did not seek it out, and several different reasons were cited as to why. Some examples include:

- Those who identified themselves as an individual learner claimed group work held no appeal;
- Some of the non-traditional students claimed the prospect of working with "teenagers" was unappealing;
- Living off-campus meant meeting suitable other students to work with was limited;
- Other students did not have the same aims.

Another interesting example came from talking to one of the mathematicians in the CSU Mathematics Department. He reflected that for his own undergraduate subjects group work was great for the subjects he did not care about. Mathematics he wanted to master, and not just part of it, and so he was willing to put in the effort to understand the subject deeply. This is not to say he was unwilling to share his understanding with other people, just not delegate to them parts he wanted to think through for himself (T. J. Penttila, personal communication, 7th December, 2012). This might explain, in part, why the "A" students interviewed mainly avoided group work. For those who were not "A" students, Hockings' observations (2009) that there is an identifiable type of student who will only accept knowledge from the instructor may go a long way to explain their reaction. Possibly, this is what Frank A meant when he said, "I generally worked with the instructor if I could do it…. When I tried to work with other people they would go off on a tangent, so that wouldn't get us any place."

Of those who did seek out groups of other students to work with, it was clear that finding a suitable group did not necessarily come easily, and once a suitable group was found it was strongly suggested that group work was only effective if all members tried to look at the work separately beforehand and then shared their understanding.

Is there a need for training how to work in groups? A couple of those interviewed said they preferred group work in a project where the task is divided up and they just run with one task. In lower level education, where cooperative learning techniques are used, it is the group's responsibility that all members understand the new material (Cooper, 1990; Slavin, 1991). Is that missing here? Is this because the group is informal? How could the whole group be held accountable for each member's understanding?

Mathematics as a language.

> "Young man, in mathematics you don't understand things, you just get used to them." – attributed to John von Neumann (Zukav, 2001)

In a recent Calculus class I taught (not MATH 160) I asked a student to take the derivative of a slightly gnarly composition of two functions. She announced the answer having correctly applied the Chain Rule. When I asked her to point out the outer and inner functions for the benefit of the rest of the class, she indicated that she didn't know, but had done so many of these type of problems that she could just see the answer with certainty. This might go a long way towards explaining why a number of students I interviewed studied for MATH 160 by doing as many problems they could lay their hands on, and then only gained a grade of "B". This method would certainly be time consuming, however, it would also challenge the student's understanding, pick up their pace in solving problems, increase their ability to know when their answer is right, and also know when to get help. Such familiarity would also help when returning to study for a subsequent examination, however, if they do not combine this with some rehearsal and elaboration techniques, they may struggle to effectively discuss the definitions, or theorems, they are applying, even though they can correctly apply them.

A few of the students interviewed referred to the similarity of learning mathematics to learning a language. The study technique of doing as many different problems as possible is somewhat like the description of "comprehensible output hypothesis" theory of learning a second language (Swain as cited in Lightbown &Spada, 2006, pp 47-48). Rather than just rote learning the same sentences again and again, the student is required to internalize what they learn by challenging them to produce conversations. This method, applied to mathematics, would make those who use it quite "fluent". Indeed, this fluency would help understanding new material as it is presented in class, as the student would have a context for the new material. However, although students may be able to use mathematical language competently, they may not be able to analyze it.

A lack of "fluency" in mathematics may be why some students spend hours upon hours studying for the course with little to show for their labors. This might also contribute to the success Nelson (2011) has experienced with her students undergoing an optional oral test in the material to be covered in the upcoming examinations. These students need to prepare for this oral examination and demonstrate their fluency in the material. It is unclear how to judge a student's fluency in mathematics before they enter the classroom. However, it may be in part what the combination of CCHE index, aggregate PACe placement scores, combined with test anxiety, self-efficacy, and the perception of quality of mathematics teaching received in high school are measuring.

It is worth noting the use of this style of study, as it has been suggested that students who gained a grade a "B" might make better Supplemental Instruction mentors than an "A" student because they probably had to use better study methods to get their grade than an "A" student with "natural" ability. If Supplemental Instruction mentors are to be role models, then it may be worth paying attention to the methods that they might recommend to others.

This style of study is not really covered by the MSLQ instrument, but perhaps could be by changing a couple of the self-regulation scale prompts, such as numbers 36 and 55. The current form of these prompts is:

Prompt 36: "When reading for this course, I make up questions to help focus my reading."

Prompt 55: "I ask myself questions to make sure I understand the material I have been studying in this class."

A possible alternative:

Prompt 36: “When studying for this course, I search for and do questions to help reinforce, or challenge, my understanding.”

Prompt 55: “I do extra questions from the text (or other sources) to make sure I understand the material I have been studying in this class.”

Reflections (Limitations)

As the groups identified who struggle are small and overlapping, statistical analysis by cohort does not produce meaningful results. Combining by other means, for example, by fall or spring semesters, has managed to increase the data but is based upon the assumption that other factors remain largely the same. This is not the case. Although the course text has been the same (except for an edition change), the course content has had small changes each of the semesters included for analysis, and the instructors who teach this course can change significantly each semester. Further, during Fall 2009, 2010 and Spring 2010, an intervention course was run that drew from students who had failed the first MATH 160 mid-term examination, hence, changing the character of those cohorts. Each cohort also has its own characteristics. In recent times, there have been more non-traditional students attempting the course; some semesters will have more students repeating the course, and more confounding factors may exist than can be identified from the data supplied by the CSU Registrar’s Office.

This study is also limited by who chose to come forward to be interviewed. There is no way of determining how representative the interviewees were of the cohorts they came from. Roughly half of those who volunteered to be interviewed were former students of the researcher, curious to know what the researcher was up to, and a half, which slightly overlapped the former group, were non-traditional students generously volunteering their time for someone's research. All the different reasons why students walked away from Math 160 would have been worth analyzing, however, of the fifteen students contacted via email after they failed to show up to a mid-term examination during the Fall 2012 semester, only two ventured any indication as to why they walked away.

Future Research

There are several avenues that could be followed from here. First, the predictive value of the model analyzed in phase three may be improved if the student's intrinsic interest in the major they were taking was measured instead of the student's intrinsic interest in MATH 160, This should be included in the model, either using a new instrument or seeking permission to adapt MSLQ as indicated above. This, combined with the student completing a shortened MSLQ survey and a compulsory placement examination, could be used in an early attempt to identify students who might struggle, and determine if diverting them to an appropriate intervention course would have success.

Alternatively, as pilot testing showed, students might give answers as to what they think they should do to study, rather than what they actually do if the survey was run too early. The first mid-term examination might again be the place to identify students who are struggling, and after this mid-term examination, determine if diverting these struggling students to a five-credit course that provides more structure to the student's out of class study activities would reduce fail/drop rates. To add incentive, the intervention course could spend some time recovering material already presented, and offer a retest to replace the first mid-term examination score.

An entirely different line of research could also be fruitful. While interviewing Andrea, she mentioned she was a music student, and as a child she played math games while in the car with her mother. A number of the mathematics graduate students at CSU are also musically trained. A few also remembered either playing math games as children, or having an older sibling teaching them math during the summer break. As reading to children, and listening to them read, is important for the development of a child's literacy (Martin-Chang & Gould, 2012), perhaps familiarity with mathematics, or symbolic music notation, in childhood is also important to develop mathematics self-efficacy, or fluency, in adults. Shepherd, Selden and Selden (2012) suggest self-efficacy in reading mathematics textbooks comes from past experience in reworking, and successfully correcting misunderstandings. Perhaps it might also come from familiarity with material written in a dense notation, such as a music score, or by playing math games where mistakes can be corrected in a nurturing environment.

Conclusions

The reasons why students fail or withdraw can be complex, hence, those likely to fail or withdraw are not easy to accurately predict. The groups identified as being susceptible were: those requiring at least a "B" grade to enter the course they wanted; non-traditional students taking on a full-time load without either completely understanding the demands this will make of their time, or how to best put the time they allocated to it; and members of the ten a.m. fall classes. Members of the first two groups might benefit from advice during an orientation period as to how much to take on in the semester in which they attempt MATH 160, as well as how to structure and use their study time (Robyak, 1978). Nearly all students interviewed, and many who responded to the study survey, spent a lot of time on this course. The difference between success and failure seemed to be how the successful students spent that time. The successful students had more study strategies, challenged their understanding more, and spent less of that time on just keeping up with due assignments. It is possible the unsuccessful students would benefit by more guidance as to how to spend their study time.

The current MATH 160 course is a service course that caters to a very wide range of needs. The students themselves come from a broad range of backgrounds and they can react very differently to the same course, for example, two of the interviewees had the same instructor, in the same semester, and had two very different opinions of both the course and instructor. There may be a benefit to dedicating some teaching sections to specific needs. For example, sections geared towards engineering students could just use relevant engineering examples, whereas a section aimed at mathematics teachers could use a far broader range of examples from, say, biology, economics, manual arts, and pure mathematics. Indeed, a section aimed just at mathematics majors could contain more than just calculus, as is the case in freshmen mathematics courses taught in British Commonwealth countries (James, Montelle, & Williams, 2007).

As teaching experience is often an important inclusion on an instructor's Curriculum Vitae, the instructors may benefit from more feedback about their teaching to reflect upon, either from the students they teach or the course coordinator, regardless of whether the instructor has taught before.

Ultimately, the student is responsible for the decisions they make when embarking upon the degree program they choose. If those that need extra guidance can be advised appropriately, and if needed, diverted to suitable intervention programs, then there may be a small improvement in the pass rate for MATH 160. However, it must be recognized that a student may not have chosen a major suited to them, or circumstances beyond their control lead them to leave before they have completed the course. We may need to accept there will be students who withdraw from the course and take a different direction in their lives.

EPILOGUE

It is evident to me that it is very difficult to predict who will fail or who will withdraw from MATH 160. Many of the issues that came to light in the course of this study made it clear the reasons for failure/drop are quite diverse.

Two areas where the Mathematics department at CSU could focus their attention relate to a prospective student's "fluency" in mathematics, and the student's ability in general to study any subject. The first could be addressed by requiring a prospective student adequately pass a placement test to gain admission into MATH 160. If the current PACe placement test is used then the entry requirement should be higher (it is currently set at the level of a "D" pass). For the combined fall data analyzed in this study, if the cutoff had been set to thirty (out of a maximum total of fifty five), 86 of the 115 Intra University students who did the PACe placement test and subsequently failed MATH 160, would have been directed to another course.

The other course these students are directed to could be an intervention course. In Fall 2014 Dr. Pilgrim will be running an intervention version of the MATH 160 course on the main campus of CSU, which is to take two semesters for the student to complete. A number of changes from the current course will be made including targeting student study skills for improvement, and specifically working to improve student proficiency (or "fluency") in the algebra and trigonometry required for a calculus course at this level as part of the course. Certainly the results of this thesis support this approach.

Perhaps the sections for this intervention could be run at ten a.m. ….

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APPENDIX A: INSTITUTIONAL REVIEW BOARD EXEMPTION FOR HISTORICAL DATA

Colorado State University

Research Integrity & Compliance Review Office
Office of Vice President for Research
Fort Collins, CO 80523-2011
(970) 491-1553
FAX (970) 491-2293

Date: December 19, 2011

To: Gene Gloeckner, Education
Mary Worthley, Education

Janell Barker

From: Janell Barker, IRB Coordinator

Re: Exploring the Failure/Drop Rate for Freshman STEM Students

After review of information regarding the secondary anonymous data to be analyzed for the above-mentioned project, it was determined that the data did not meet the requirements of the federal definition of human subject research. "Human subject means a living individual about whom an investigator conducting research obtains data through intervention or interaction with the individual, or identifiable private information."

Living individual – Y
About Whom – Y
Intervention/Interaction – N
Identifiable Private Information – N

Thank you for submitting this information. If you have more projects that are similar, please contact us prior to submission. The IRB must determine whether a project needs to have IRB approval.

Animal Care & Use • Human Research • Institutional Biosafety
321 General Services Building http://web.research.colostate.edu/ricro/

APPENDIX B: INSTITUTIONAL REVIEW BOARD APPROVAL FOR STUDY

Research Integrity & Compliance Review Office
Office of the Vice President for Research
321 General Services Building - Campus Delivery 2011 Fort Collins, CO
TEL: (970) 491-1553
FAX: (970) 491-2293

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE:	July 27, 2012	
TO:	Gloeckner, Gene, School of Education Lehmann, Jean, School of Education, Worthley, Mary	
FROM:	Barker, Janell, Coordinator, CSU IRB 2	
PROTOCOL TITLE:	A mixed methods explanatory study of the failure/drop rate for freshmen STEM calculus students.	
FUNDING SOURCE:	NONE	
PROTOCOL NUMBER:	11-2641H	
APPROVAL PERIOD:	Approval Date: July 15, 2012	Expiration Date: June 21, 2013

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: A mixed methods explanatory study of the failure/drop rate for freshmen STEM calculus students.. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

Janell Barker, Senior IRB Coordinator - (970) 491-1655 Janell.Barker@Colostate.edu
Evelyn Swiss, IRB Coordinator - (970) 491-1381 Evelyn.Swiss@Colostate.edu

Barker, Janell

Janell Barker

Barker, Janell

Approval is to recruit up to 550 Math 160 students (survey portion); and 40 students for the interview phase. INTERVIEWS: The above-referenced project was approved by the Institutional Review Board with the condition that the approved consent form is signed by the subjects and each subject is given a copy of the form. NO changes may be made to this document without first obtaining the approval of the IRB. SURVEYS: Because of the nature of this research, it will not be necessary to obtain a signed consent form. However, all subjects must be consented with the approved electronic cover letter.

Approval Period:	July 15, 2012 through June 21, 2013
Review Type:	EXPEDITED
IRB Number:	00000202

APPENDIX C: PILOT ONE INSTRUMENT CONSTRUCTS AND RELIABILITY

Table C1.
Study Constructs and Sub Constructs which are part of the R-SPQ-2F Instrument.

Approach	**Sub constructs**	
	Motive	**Strategy**
Surface (SA) - student does minimum requirement to complete course/subject.	(SM) To do the minimal amount of work required to not fail.	(SS) Only do the bare essentials. Often utilises rote learning.
Deep (DA) - student is intrinsically interested in what is being learned.	(DM) To develop high ability in the subject of interest.	(DS) Will read widely and make connections with existing knowledge.

Table C2.
Three Constructs from the Indiana Mathematical Beliefs Scale.

Constructs	**Description**
'I can solve time consuming problems' (SOL)	This covers the belief most mathematics problems can be solved in less than 5 minutes, which would be the experience of many high school students. Someone with this belief may give up if it takes longer.
'Understanding concepts is important in Mathematics' (CON)	This is trying to identify those who believe they only need to memorize parts of mathematics in order to 'pass'. The procedures they memories they do not try to understand.
'Mathematics is useful in daily life' (USE)	Here the belief mathematics in the classroom is removed from the real world is measured.

Table C3.
Reliability Statistics for R-SPQ-2F Instrument.

Construct/ Sub constructs	Cronbach's Alphas from Biggs, Kember and Leung (2001) (*N* = 495)	Cronbach's Alphas from Immekus and Imbrie (2009)	
		Cohort 1 (*N* = 1,490)	Cohort 2 (*N* = 1,533)
Deep Approach	0.73	0.76	0.76
Deep Motive	0.62	0.65	0.67
Deep Strategy	0.63	0.66	0.65
Surface Approach	0.64	0.73	0.70
Surface Motive	0.72	0.63	0.57
Surface Strategy	0.57	0.72	0.71

Table C4.
Relationship between items and constructs.

Construct/ Sub construct	Calculation of Related Items
Deep motive	Sum of the Likert scores for items 1, 5, 9, 13, and 17.
Deep Strategy	Sum of the Likert scores for items 2, 6, 10, 14 and 18.
Surface Motive	Sum of the Likert scores for items 3, 7, 11, 15, and 19.
Surface Strategy	Sum of the Likert scores for items 4, 8, 12, 16, and 20.
Deep approach	Sum of the deep motive and deep strategy scores.
Surface approach	Sum of the surface motive and surface strategy scores.

Table C5.
Reliability Statistics for IMBS constructs and USE construct

Construct	Cronbach's Alphas from Kloosterman and Stage (1992) (*N* = 251)	Cronbach's Alphas from Pilgrim (2010) (*N* = 476)
I can solve time-consuming mathematics problems	0.80	0.76
Understanding concepts is important in mathematics	0.81	0.81
Mathematics is useful in daily life	0.87	0.77

Table C6.
Pilot study correlation results.

Construct/ Sub constructs	Exam 1 (n = 378)	Exam 2 (n = 360)	Exam 3 (n = 305)	Final Grade (n = 323)
Deep Approach	0.01	-0.02	-0.09	0.07
Deep Motive	0.05	0.02	-0.05	0.13^{*}
Deep Strategy	-0.03	-0.07	-0.12	-0.03
Surface Approach	-0.10	-0.07	-0.04	-0.12^{*}
Surface Motive	-0.05	-0.02	0.01	-0.09
Surface Strategy	-0.12^{*}	-0.10	-0.08	-0.12^{*}
I can solve time-consuming mathematics problems	0.18^{***}	0.13^{*}	0.09	0.21^{**}
Understanding concepts is important in mathematics	0.13^{**}	0.06	0.12^{*}	0.12^{*}
Mathematics is useful in daily life	0.11^{*}	0.13^{*}	0.08	0.16^{**}

* $p < 0.05$ level
** $p < 0.01$ level

APPENDIX D: PILOT TWO INSTRUMENT CONSTRUCTS AND RELIABILITY

Table D1.
Categories, Components, and Subscales used in the MSLQ instrument.

Categories	**Components**	**Subscales**	**Variable Name**	**Alpha Pintrich et al.**	**Pilot 2 alpha**	**Fall 2012 alpha**
Motivation	Value	Intrinsic Goal Orientation	Intr	0.74	0.72	
		Extrinsic Goal Orientation	Extr	0.62	0.66	
		Task Value	Tskv	0.90	0.88	
	Expectancy	Control Beliefs	Cont	0.68	0.71	.71
		Self Efficacy	Slfef	0.93	0.93	.93
	Affective	Test Anxiety	Tanx	0.80	0.79	.84
Learning Strategies	Cognitive & Metacognitive	Rehearsal	Reh	0.69	0.76	.62
		Elaboration	Elab	0.76	0.78	.70
		Organization	Org	0.64	0.75	.66
		Critical Thinking	Crit	0.80	0.79	
		Self-Regulation	Mcg	0.79	0.80	
	Resource Management	Time and Study Environment	Tsdy	0.76	0.80	.80
		Effort Regulation	Eff	0.69	0.73	.66
		Peer Learning	Prlrn	0.76	0.82	
		Help Seeking	Hsk	0.52	0.66	.62

Table D2.
Correlation to First Mid-term Examination score.

Variable	**Correlation to Exam 1 score**	***n***	***M***	***SD***
Control Beliefs	.17**	226	17.60	3.23
Self efficacy for learning and performance	.38**	224	32.96	7.84
Test Anxiety	-.24**	222	19.35	5.14
Effort Regulation	.14*	222	20.18	3.29
Mean score for Exam 1	63.23	228		
Standard Deviation for Exam 1	21.66	228		

* p = 0.05
** p = 0.01

APPENDIX E: VARIABLES

The following table is a summary of the variables:

Table E1.
Summary of variables.

Variable	IV or DV	Number of levels	Level of Measurement
Final grade	DV	11	Nominal.
Final grade score numerical equivalent	DV	11	Nominal but treated as scale.
Mid term score	DV	Continuous	Scale. Approximately normal.
Semester/year	IV	10	Nominal.
Semester	IV	3	Nominal: fall, spring or summer.
Repeat status	IV	2	Dichotomous
Intervention	IV	2	Dichotomous
Withdraw	IV	2	Dichotomous
Primary College	IV: attribute	4	Nominal
Class	IV: attribute	5	Nominal
CCHE index score	IV: attribute	Continuous	Scale.
Raw PACe aggregate score	IV: attribute	Continuous	Scale
ACT Math	IV	Continuous	Scale
ACT Composite	IV	Continuous	Scale
SAT Math	IV	Continuous	Scale
SAT Combined	IV	Continuous	Scale
Intrinsic (MSLQ)	IV	Continuous	Scale
Extrinsic (MSLQ)	IV	Continuous	Scale
Task Value (MSLQ)	IV	Continuous	Scale
Control Beliefs (MSLQ)	IV	Continuous	Scale
Self Efficacy (MSLQ)	IV	Continuous	Scale
Test Anxiety (MSLQ)	IV	Continuous	Scale
Rehearsal (MSLQ)	IV	Continuous	Scale
Elaboration (MSLQ)	IV	Continuous	Scale

Variable	IV or DV	Number of levels	Level of Measurement
Organization (MSLQ)	IV	Continuous	Scale
Critical Thinking (MSLQ)	IV	Continuous	Scale
Self-Regulation (MSLQ)	IV	Continuous	Scale
Time and Study Environment (MSLQ)	IV	Continuous	Scale
Effort Regulation (MSLQ)	IV	Continuous	Scale
Peer Learning (MSLQ)	IV	Continuous	Scale
Help Seeking (MSLQ)	IV	Continuous	Scale
Deep motive (SPQ)	IV	Continuous	Scale
Deep strategy (SPQ)	IV	Continuous	Scale
Deep approach (SPQ)	IV	Continuous	Scale
Surface motive (SPQ)	IV	Continuous	Scale
Surface strategy (SPQ)	IV	Continuous	Scale
Surface approach (SPQ)	IV	Continuous	Scale
Solve time consuming problems (IMBS)	IV	Continuous	Scale
Understanding important in Math (IMBS)	IV	Continuous	Scale
Math is useful (Usefulness scale)	IV	Continuous	Scale

APPENDIX F: PILOT ONE INSTRUMENT

Permission to use the Indiana Mathematics Beliefs Scales

Re: Indiana Mathematics Beliefs Scales

From: **Kloosterman, Peter W.** (klooster@indiana.edu)
Sent: Thu 12/02/10 9:43 AM
To: worthley (worthley@lamar.colostate.edu)
Cc: kenk@math.colostate.edu (kenk@math.colostate.edu); Gene.Gloeckner@ColoState.EDU (Gene.Gloeckner@ColoState.EDU); mary.worthley@ColoState.EDU (mary.worthley@ColoState.EDU)

1 attachment
Berkaliev & Kloosterman SSM.pdf (2.5 MB)

Mary,
You are welcome to use the scales and modify to meet your needs (because the items are published in a national journal, the only restriction is that you can't make money on the items yourself). I know the scales have been used in a number of studies by other individuals but I haven't kept track of those. In case you don't have it, I'm attaching a recent article where the scales were used with engineering students although for a different purpose than what you are doing.

Good luck with your project.

Peter Kloosterman
Martha Lea and Bill Armstrong Professor for Teacher Education
Professor of Mathematics Education
School of Education, Room 3214
Indiana University
Bloomington, IN 47405

klooster@indiana.edu
(812) 856-8147
http://profile.educ.indiana.edu/klooster

On 12/2/10 10:20 AM, "worthley" <worthley@lamar.colostate.edu> wrote:

>
> Dear Dr. Kloosterman and Dr. Stage,
>
> My name is Mary Worthley and I am a PhD student at Colorado State University. I will be doing my dissertation on success in freshman Calculus courses for scientists and engineers. I am following up on a study conducted by Mary Pilgrim who used your Indiana Mathematics Beliefs Scales as part of her study. After consultations with members of my committee and others who teach calculus here at CSU, we have decided that parts of this instrument would be valuable as a tool in our follow up study.
>
> Part of the aim of my follow up study is to determine if there is an association between the student¹s beliefs about mathematics and how they are approach studying this subject. I also wish to determine if there is an association between the student¹s beliefs and the rate they fail the course or the reasons that they chose to not complete the course.
>
> Of course I need permission from you in order to acquire our Institutional Review Board approval here at Colorado State University. So with your permission I wish to use the constructs: ŒI can solve time-consuming mathematics problems¹; and ŒUnderstanding concepts is important in

Permission to use Mathematics usefulness scale.

Re: mathematics usefulness scale

From: **Elizabeth Fennema** (efennema@wisc.edu)
Sent: Thu 12/02/10 8:33 PM
To: worthley (worthley@lamar.colostate.edu)

```
On 12/2/2010 8:25 AM, worthley wrote:
> Dear Dr. Fennema,
>
> My name is Mary Worthley and I am a PhD student at Colorado State
> University. I will be doing my dissertation on success in freshman Calculus
> courses for scientists and engineers. I am following up on a study
> conducted by Mary Pilgrim who used your Mathematics Usefulness Scale as
> part of her study. After consultations with members of my committee and
> others who teach calculus here at CSU, we have decided that parts of this
> instrument would be valuable as a tool in our follow up study.
>
> Part of the aim of my follow up study is to determine if there is an
> association between the student's beliefs about mathematics and how they
> are approach studying this subject. I also wish to determine if there is an
> association between the student's beliefs and the rate they fail the course
> or the reasons that they chose to not complete the course.
>
> Of course I need permission from you in order to acquire our Institutional
> Review Board approval here at Colorado State University. So with your
> permission I wish to use your instrument 'Mathematics Usefulness Scale'.
>
> All I need from you is an email allowing us to use and alter the
> instrument. Of course, we would send you a copy of any alterations made.
>
> In addition, if you are aware of any other studies that have used your
> instrument I would be very interested.
>
> Thank you very much for your time and consideration.
>
> Yours sincerely,
> Mary Worthley
> mary.worthley@colostate.edu
>
Dear Mary Worthley,

You have my permission to use any of the Fennema-Sherman Mathematics
Attitude Scales in you research provided you reference them properly.

It would be intriguing to me to understand why you are using the
usefulness Scale. I would anticipate that the Confidence Scale would be
more appropriate at the University level. But I am sure you have
thought it all out with great care.

Best Wishes for the completion of your dissertation.

Elizabeth Fennema
```

APPENDIX G: PILOT ONE INSTRUMENT

Q1 Please enter your 9 digit student ID number

Q2 This questionnaire has a number of questions about your attitudes towards your studies and your usual way of studying mathematics. There is no right way of studying. It depends on what suits your own style and the course you are studying. It is accordingly important that you answer each question as honestly as you can relating to your study of mathematics. Please choose one of the most appropriate response to each question. Thank you for your cooperation.

	never or only rarely true of me (1)	**sometimes true of me (2)**	**true of me about half the time (3)**	**frequently true of me (4)**	**always or almost always true of me (5)**
I find I can do hard math problems if I just hang in there. (1)	❍	❍	❍	❍	❍
I think that a person who doesn't understand why an answer to a math problem is correct hasn't really solved the problem. (2)	❍	❍	❍	❍	❍
I think studying math is a waste of time. (3)	❍	❍	❍	❍	❍
I find that at times studying gives me a feeling of deep personal satisfaction (4)	❍	❍	❍	❍	❍
I find that I have to do enough work on a topic so that I can form my own conclusions before I am satisfied. (5)	❍	❍	❍	❍	❍
My aim is to pass the course while doing as little work as possible. (6)	❍	❍	❍	❍	❍
I only study seriously what's given out in class or in the course outlines (7)	❍	❍	❍	❍	❍
I feel I can do math problems that take a long time to complete (8)	❍	❍	❍	❍	❍
I believe knowing math will help me earn a living (9)	❍	❍	❍	❍	❍
I think it doesn't matter if you understand a math problem if you get the right answer (10)	❍	❍	❍	❍	❍

	never or only rarely true of me (1)	sometimes true of me (2)	true of me about half the time (3)	frequently true of me (4)	always or almost always true of me (5)
I feel that virtually any topic in math can be highly interesting once I get into it (11)	❍	❍	❍	❍	❍
I find most new topics in math interesting and often spend extra time trying to get more information about them (12)	❍	❍	❍	❍	❍
I do not find my math course very interesting so I keep my work to the minimum (13)	❍	❍	❍	❍	❍
I learn some things by rote until I know them by heart even if I do not understand them (14)	❍	❍	❍	❍	❍
If I can't solve math problems quickly I quit trying (15)	❍	❍	❍	❍	❍
I think getting a right answer in math is more important than understanding why an answer works (16)	❍	❍	❍	❍	❍
I believe Math has no relevance to my life (17)	❍	❍	❍	❍	❍
I find studying math topics can at times be as exciting as a good novel or movie (18)	❍	❍	❍	❍	❍
I test my self on important topics until I understand them completely (19)	❍	❍	❍	❍	❍
I find I can get by in most assessments by memorizing key sections rather than trying to understand them (20)	❍	❍	❍	❍	❍
I generally restrict my study to what is specifically set as I think it is unnecessary to do anything extra (21)	❍	❍	❍	❍	❍
Math problems that take a long time don't bother me (22)	❍	❍	❍	❍	❍

	never or only rarely true of me (1)	sometimes true of me (2)	true of me about half the time (3)	frequently true of me (4)	always or almost always true of me (5)
I think it's not important to understand why a math procedure works as long as it gives the correct answer (23)	❍	❍	❍	❍	❍
I believe math is a worthwhile and necessary subject (24)	❍	❍	❍	❍	❍
I work hard at math because I find the material interesting (25)	❍	❍	❍	❍	❍
I spend a lot of my free time finding out more about interesting topics which have been discussed in class (26)	❍	❍	❍	❍	❍
I find it is not helpful to study a topic in depth (27)	❍	❍	❍	❍	❍
I believe that instructors shouldn't expect students to spend significant amounts of time studying material everyone knows wont be examined (28)	❍	❍	❍	❍	❍
I'm not good at solving math problems that take a while to figure out (29)	❍	❍	❍	❍	❍
I think time used to investigate why a solution to a math problem works is time well spent (30)	❍	❍	❍	❍	❍
I think math will not be important to me in my life's work (31)	❍	❍	❍	❍	❍
I come to most classes with questions in mind that I want answering (32)	❍	❍	❍	❍	❍
I make a point of looking at most of the suggested readings that go with the class (33)	❍	❍	❍	❍	❍
I see no point in learning material which is not likely to be in the examination (34)	❍	❍	❍	❍	❍

	never or only rarely true of me (1)	sometimes true of me (2)	true of me about half the time (3)	frequently true of me (4)	always or almost always true of me (5)
I find the best way to pass exams is to try to remember answers to likely questions (35)	❍	❍	❍	❍	❍
If I can't do a math problem in a few minutes I probably can't do it at all (36)	❍	❍	❍	❍	❍
I study math because I know how useful it is (37)	❍	❍	❍	❍	❍
I think in addition to getting the right answer in math, it is important to understand why the answer is correct (38)	❍	❍	❍	❍	❍

Q3 What is your major?

Q4 What is a typical number of hours per week you spend on paid employment?

Q5 What is a typical number of hours per week you spend on volunteer work?

Q6 What is the number of credit hours you are currently enrolled at CSU?

Q7 What is the number of credit hours you are currently enrolled in elsewhere?

Q8 During semester do you live on or off campus?

- On (1)
- Off (2)

Q9 Which one of the following statements best describes how you satisfied the prerequisites for MATH 160?

- I took the CSU Math Placement Exam and placed into MATH 160. (1)
- I took one or more PACe courses at CSU. (2)
- I had transfer credits that placed me into MATH 160. (Please explain below.) (3) ____________________
- I had AP credit. (4)
- I had IB credit. (5)
- I received departmental approval for having taken two semesters of calculus in high school with a grade of B of higher each semester. (6)

Q10 Which one of the following statements best describes your prior experience with calculus?

- I have not taken calculus at all before. (1)
- I had a brief introduction to calculus in a high school course (such as pre-calculus). (2)
- I took half a year of calculus in high school. (3)
- I took a full year of calculus (not AP) in high school. (4)
- I took a full year of AP calculus in high school. I received the following grade in this class (5) ____________________

- I started a college calculus course but withdrew (formally or informally) and didn't finish the course. The title of course I withdrew from was (6) ____________________
- I finished a college calculus course other than MATH 160. (Please explain below, including the university.) (7) ____________________
- I am repeating MATH 160. (State all the semester(s) and year(s) in which you previously took MATH 160.) (8) ____________________

Answer If Which one of the following statements best describes your... I took a full year of AP calculus in high school. I received the following grade in this class Is Selected

Q11 For those that took a full year of AP Calculus in high school: I received a score of:

- 1 (1)
- 2 (2)
- 3 (3)
- 4 (4)
- 5 (5)
- Did not take it. (6)

Q12 Please list other subjects currently enrolled in:

APPENDIX H: PILOT TWO INSTRUMENT

Q1 For 10 points to be credited to your homework please enter your 9 digit student ID number accurately.

Q2 The following questions ask about your motivation for, and attitudes about, this class. Remember there are no right or wrong answers, just answer as accurately as possible. Use the scale below to answer the questions using the prompt that best describes you.

	never true of me (1)	**rarely true of me (2)**	**more often not true of me than true (3)**	**more often true of me than not (4)**	**frequently true of me (5)**	**always true of me (6)**
In a class like this, I prefer course material that really challenges me so I can learn new things. (1)	❍	❍	❍	❍	❍	❍
If I study in appropriate ways, then I will be able to learn the material in this course. (2)	❍	❍	❍	❍	❍	❍
When I take a test I think about how poorly I am doing compared with other students. (3)	❍	❍	❍	❍	❍	❍
I think I will be able to use what I learn in this course in other courses. (4)	❍	❍	❍	❍	❍	❍
I believe I will receive an excellent grade in this class. (5)	❍	❍	❍	❍	❍	❍
I'm certain I can understand the most difficult material presented in the readings for this course. (6)	❍	❍	❍	❍	❍	❍
Getting a good grade in this class is the most satisfying thing for me right now. (7)	❍	❍	❍	❍	❍	❍
When I take a test I think about items on other parts of the test I can't answer. (8)	❍	❍	❍	❍	❍	❍

	never true of me (1)	rarely true of me (2)	more often not true of me than true (3)	more often true of me than not (4)	frequently true of me (5)	always true of me (6)
It is my own fault if I don't learn the material in this course. (9)	❍	❍	❍	❍	❍	❍
It is important for me to learn the course material in this class. (10)	❍	❍	❍	❍	❍	❍
The most important thing for me right now is improving my overall grade point average, so my main concern in this class is getting a good grade. (11)	❍	❍	❍	❍	❍	❍
I'm confident I can learn the basic concepts taught in this class. (12)	❍	❍	❍	❍	❍	❍
If I can, I want to get better grades in this class than most of the other students. (13)	❍	❍	❍	❍	❍	❍
When I take tests I think of the consequences of failing. (14)	❍	❍	❍	❍	❍	❍
I'm confident I can understand the most complex material presented by the instructor in this course. (15)	❍	❍	❍	❍	❍	❍
In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn. (16)	❍	❍	❍	❍	❍	❍
I am very interested in the content area of this course. (17)	❍	❍	❍	❍	❍	❍
If I try hard enough, then I will understand the course material. (18)	❍	❍	❍	❍	❍	❍

	never true of me (1)	rarely true of me (2)	more often not true of me than true (3)	more often true of me than not (4)	frequently true of me (5)	always true of me (6)
I have an uneasy, upset feeling when I take an exam. (19)	❍	❍	❍	❍	❍	❍
I'm confident I can do an excellent job on the assignments and tests in the is course. (20)	❍	❍	❍	❍	❍	❍
I expect to do well in this class. (21)	❍	❍	❍	❍	❍	❍
The most satisfying thing for me in this course is trying is trying to understand the content as thoroughly as possible. (22)	❍	❍	❍	❍	❍	❍
I think the course material in this class is useful for me to learn. (23)	❍	❍	❍	❍	❍	❍
When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade. (24)	❍	❍	❍	❍	❍	❍
If I don't understand the course material, it is because I didn't try hard enough. (25)	❍	❍	❍	❍	❍	❍
I like the subject matter of this course. (26)	❍	❍	❍	❍	❍	❍
Understanding the subject matter of this course is very important to me. (27)	❍	❍	❍	❍	❍	❍
I feel my heart beating fast when I take an exam. (28)	❍	❍	❍	❍	❍	❍
I'm certain I can master the skills being taught in this class. (29)	❍	❍	❍	❍	❍	❍

	never true of me (1)	rarely true of me (2)	more often not true of me than true (3)	more often true of me than not (4)	frequently true of me (5)	always true of me (6)
I want to do well in this class because it is important to show my ability to my family, friends, employer, or others. (30)	❍	❍	❍	❍	❍	❍
Considering the difficulty of this course, the instructor, and my skills, I think I will do well in this class. (31)	❍	❍	❍	❍	❍	❍

Q3 The following questions ask about your learning strategies and study skills for this class. Again, there are no right or wrong answers. Answer the questions about how you study in this class as accurately as possible. Use the scale below to answer the questions using the prompt that best describes you.

	never true of me (1)	rarely true of me (2)	more often not true of me than true (3)	more often true of me than not (4)	frequently true of me (5)	always true of me (6)
When I study the readings for this course, I outline the material to help me organize my thoughts. (1)	❍	❍	❍	❍	❍	❍
During class time I often miss important points because I'm thinking of other things. (2)	❍	❍	❍	❍	❍	❍
When studying for this course, I often try to explain the material to a classmate or friend. (3)	❍	❍	❍	❍	❍	❍
I usually study in a place where I can concentrate on my course work. (4)	❍	❍	❍	❍	❍	❍
When reading for this course, I make up questions to help focus my reading. (5)	❍	❍	❍	❍	❍	❍
I often feel so lazy or bored when I study for this class that I quit before I finish what I planned to do. (6)	❍	❍	❍	❍	❍	❍

	never true of me (1)	rarely true of me (2)	more often not true of me than true (3)	more often true of me than not (4)	frequently true of me (5)	always true of me (6)
I often find myself questioning things I hear or read in this course to decide if I find them convincing. (7)	❍	❍	❍	❍	❍	❍
When I study for this class, I practice saying the material to myself over and over. (8)	❍	❍	❍	❍	❍	❍
Even if I have trouble learning the material in this class, I try to do the work on my own, without help from anyone. (9)	❍	❍	❍	❍	❍	❍
When I become confused about something I'm reading for this class, I go back and try and figure it out. (10)	❍	❍	❍	❍	❍	❍
When I study for this course, I go through the readings and my class notes and try to find the most important ideas. (11)	❍	❍	❍	❍	❍	❍
I make good use of my study time for this course. (12)	❍	❍	❍	❍	❍	❍
If course readings are difficult to understand, I change the way I read the material. (13)	❍	❍	❍	❍	❍	❍
I try to work with other students from this class to complete the course assignments. (14)	❍	❍	❍	❍	❍	❍
When studying for this course, I read my class notes and the course readings over and over again. (15)	❍	❍	❍	❍	❍	❍

	never true of me (1)	rarely true of me (2)	more often not true of me than true (3)	more often true of me than not (4)	frequently true of me (5)	always true of me (6)
When a theory, interpretation, or conclusion is presented in class or in the readings, I try to decide if there is good supporting evidence. (16)	❍	❍	❍	❍	❍	❍
I work hard to do well in this class even if I don't like what we are doing. (17)	❍	❍	❍	❍	❍	❍
I make simple charts, diagrams, or tables to help me organize course material. (18)	❍	❍	❍	❍	❍	❍
When studying for this course, I often set aside time to discuss course material with a group of students from the class. (19)	❍	❍	❍	❍	❍	❍
I treat the course material as a starting point and try to develop my own ideas about it. (20)	❍	❍	❍	❍	❍	❍
I find it hard to stick to a study schedule. (21)	❍	❍	❍	❍	❍	❍
When I study for this class, I pull together information from different sources, such as lectures, readings, and discussions. (22)	❍	❍	❍	❍	❍	❍
Before I study new course material thoroughly, I often skim it to see how it is organized. (23)	❍	❍	❍	❍	❍	❍
I ask myself questions to make sure I understand the material I have been studying in this class. (24)	❍	❍	❍	❍	❍	❍
I try to change the way I study in order to fit the course requirements and the instructor's teaching style. (25)	❍	❍	❍	❍	❍	❍

	never true of me (1)	rarely true of me (2)	more often not true of me than true (3)	more often true of me than not (4)	frequently true of me (5)	always true of me (6)
I often find that I have been reading for this class but don't know what it was all about. (26)	❍	❍	❍	❍	❍	❍
I ask the instructor to clarify concepts I don't understand well. (27)	❍	❍	❍	❍	❍	❍
I memorize key words to remind me of important concepts in this class. (28)	❍	❍	❍	❍	❍	❍
When course work is difficult, I either give up or only study the easy parts. (29)	❍	❍	❍	❍	❍	❍
I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for this course. (30)	❍	❍	❍	❍	❍	❍
I try to relate ideas in this subject to those in other courses whenever possible. (31)	❍	❍	❍	❍	❍	❍
When I study for this course, I go over my class notes and make an outline of important concepts. (32)	❍	❍	❍	❍	❍	❍
When reading for this class, I try to relate the material to what I already know. (33)	❍	❍	❍	❍	❍	❍
I have a regular place set aside for studying. (34)	❍	❍	❍	❍	❍	❍
I try to play around with ideas of my own related to what I am learning in this course. (35)	❍	❍	❍	❍	❍	❍

	never true of me (1)	rarely true of me (2)	more often not true of me than true (3)	more often true of me than not (4)	frequently true of me (5)	always true of me (6)
When I study for this course, I write brief summaries or the main ideas from the readings and my class notes. (36)	❍	❍	❍	❍	❍	❍
When I can't understand the material in this course, I ask another student in this class for help. (37)	❍	❍	❍	❍	❍	❍
I try to understand the material in this class by making connections between the readings and the concepts from the lectures. (38)	❍	❍	❍	❍	❍	❍
I make sure that I keep up with the weekly readings and assignments for this course. (39)	❍	❍	❍	❍	❍	❍
Whenever I read of hear an assertion or conclusion in this class, I think about possible alternatives. (40)	❍	❍	❍	❍	❍	❍
I make lists of important items for this course and memorize the list. (41)	❍	❍	❍	❍	❍	❍
I attend this class regularly. (42)	❍	❍	❍	❍	❍	❍
Even when course materials are dull and uninteresting, I manage to keep working until I finish. (43)	❍	❍	❍	❍	❍	❍
I try to identify students in this class whom I can ask for help if necessary. (44)	❍	❍	❍	❍	❍	❍
When studying for this course I try to determine which concepts I don't understand well. (45)	❍	❍	❍	❍	❍	❍

	never true of me (1)	rarely true of me (2)	more often not true of me than true (3)	more often true of me than not (4)	frequently true of me (5)	always true of me (6)
I often find that I don't spend very much time on this course because of other activities. (46)	❍	❍	❍	❍	❍	❍
When I study for this class, I set goals for myself in order to direct my activities in each study period. (47)	❍	❍	❍	❍	❍	❍
If I get confused taking notes in class, I make sure I sort it out afterwards. (48)	❍	❍	❍	❍	❍	❍
I rarely find time to review my notes or readings before an exam. (49)	❍	❍	❍	❍	❍	❍
I try to apply ideas from course readings in other class activities such as lecture and discussion. (50)	❍	❍	❍	❍	❍	❍

APPENDIX I: BACKGROUND SURVEY AND CONSENT FORM

Q1 **Consent to Participate in a Research Study**
Colorado State University

TITLE OF STUDY: A mixed methods explanatory study of the failure/drop rate of freshman STEM calculus students.
Principal Investigator: Gene Gloeckner, School of Education CSU, Ph.D., gene.gloeckner@colostate.edu
CO-Principal Investigator: Mary Worthley, School of Education CSU, Graduate student, mary.worthley@colostate.edu

WHY AM I BEING INVITED TO TAKE PART IN THIS RESEARCH? The purpose of the study is to examine factors that influence student success in Math 160. You are invited to participate as you are a studying a freshman course in calculus.

WHO IS DOING THE STUDY? This research is part of a doctoral dissertation.

WHAT IS THE PURPOSE OF THIS STUDY? This data will be used as part of an IRB approved study. The purpose of the study is to examine factors that influence student success in a freshman course in calculus.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST? This part of the study will be conducted on-line. There will be two surveys: each on-line survey should be short and take between 10 -20 minutes to complete, depending upon how much detail you give to any open response questions.

WHAT WILL I BE ASKED TO DO? Complete this survey and complete a separate survey after the first mid-term examination. Completing this survey will count towards your homework score for this homework. Competing the separate survey after the first mid-term examination will count to the homework assignment it is attached to. If you chose to opt out, an alternative homework question will be given for you to compete that should take roughly the same length of time as the survey opted out of to complete.

WHAT ARE THE POSSIBLE RISKS DISCOMFORTS? There are no known risks associated with participating in this research. It is not possible to identify all potential risks in research procedures, but the researcher(s) have taken reasonable safeguards to minimize any known and potential, but unknown, risks.

ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY? There are no direct benefits to you personally. There is an anticipated benefit to future students of the course, as it is hoped the course will improve from your feedback.

DO I HAVE TO TAKE PART IN THE STUDY? Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

WHO WILL SEE THE INFORMATION THAT I GIVE? We will keep private all research records that identify you, to the extent allowed by law.

Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from your research records and these two things will be stored in different places under lock and key.

WILL I RECEIVE ANY COMPENSATION FOR TAKING PART IN THIS STUDY? If you complete this survey it will count as one homework score. If you choose to opt out of completing the survey an alternative homework question will be displayed instead for you to complete that should take an equivalent amount of time for you to do.

WHAT IF I HAVE QUESTIONS? If you have questions about the study, then please contact the investigator, Mary Worthley at mary.worthley@colostate.edu before you complete the survey. If you have any questions about your rights as a volunteer in this research, contact Janell Barker, Human Research Administrator at 970-491-1655. We will give you a copy of this consent form to take with you.

This consent form was approved by the CSU Institutional Review Board for the protection of human subjects in research on 15th July, 2012.

WHAT ELSE DO I NEED TO KNOW? Please select all of the appropriate options from below. If you select either (or both) of the first two options you will be taken to the survey. If you select the third option you will be taken to the alternative homework question.

- ❑ I have read and understood the above and consent to allow access to my exam results for this semester for this study. (1)
- ❑ I have read and understood the above and consent to allow access to this data (with any personal identification data removed) for other studies. (2)
- ❑ I have read and understood the above and do not wish to participate. (3)

If I have read and understood ... Is Selected, Then Skip To Sterling Sand and Gravel Company quar...

Q2 To have your homework score updated please correctly type in your 9 digit student id number.

Q3 What is the minimum grade do you need to get in this class? (e.g. for your major, or to meet a scholarship requirement, etc)

- ❍ A (1)
- ❍ B (2)
- ❍ C (3)
- ❍ D (4)
- ❍ I am only Auditing this class (5)

Answer If What is the minimum grade do you need to get in this clas... A Is Selected
Q4 Is this minimum grade a major requirement or a scholarship requirement or other (please specify)?

Q5 Which is more true of you?

- ❍ Chose your major and then chose to attend CSU. (1)
- ❍ Chose to attend CSU and then chose your major. (2)

Q6 What is the average number of hours per week you spent on math homework at high school (or previous math course if high school was more than 5 years ago)?

Q7 What is the average number of hours per week you spent preparing for a math test at high school (or previous math course if high school was more than 5 years ago)?

Q8 What is the average number of hours per week you spent on studying math (other than the above) at high school (or previous math course if high school was more than 5 years ago)?

Q9 How easy do you find math?

- ❍ Very easy (1)
- ❍ Easy (2)
- ❍ Some parts easy, other parts hard (3)
- ❍ Not easy (4)
- ❍ Can pass with tutoring (5)
- ❍ A complete struggle (6)

Q10 During semester do you live on or off campus?

- ❍ On (1)
- ❍ Off (2)

Q11 Which one of the following statements best describes the size of the last high school you attended?

- ❍ Small (< 400 enrolled) (1)
- ❍ Medium (400 - 2000 enrolled) (2)
- ❍ Large (> 2000 enrollments) (3)

Q12 Which one of the following statements best describes the quality of teaching at the last high school you attended?

- ❍ Low (1)
- ❍ Some teachers good, others not so good (2)
- ❍ OK (3)
- ❍ Excellent (4)

Q13 Which one of the following statements best describes your prior experience with calculus?

- ❍ I have never completed a course in calculus at all before. (1)
- ❍ I took calculus (not AP) in high school. (2)
- ❍ I took a full year of AP calculus in high school. (3)
- ❍ I finished a college calculus course other than MATH 160. I received the following grade (4) ____________________
- ❍ I am repeating MATH 160. (State all the semester(s) and year(s) in which you previously took MATH 160.) (5) ____________________

Answer If Which one of the following statements best describes your... I am repeating MATH 160. (State all the semester(s) and year(s) in which you previously took MATH 160.) Is Selected

Q14 For those that took a full year of AP Calculus in high school: I received a score of:

- ❍ 1 (1)
- ❍ 2 (2)
- ❍ 3 (3)
- ❍ 4 (4)
- ❍ 5 (5)
- ❍ Did not take exam. (6)

Q15 Please list other subjects currently enrolled in:

Q16 Please list three qualities that you believe a person requires to study calculus at university.

1. (1)
2. (2)
3. (3)

Q17 Please indicate which, if any, of these three qualities you believe you have.

1. (1)
2. (2)
3. (3)

Answer If Consent to Participate in a Research Study Colorado St... I have read and understood the above and do not wish to participate. Is Selected

Q18 Sterling Sand and Gravel Company quarries sand and gravel from a pit along the river. Sand is separated from the gravel, washed, and carried to a pile by a conveyor belt. Because of the physical characteristics of the sand, the pile of sand is always a cone with height equal to the diameter of its base. When Sandy returns from lunch,he finds that the pile of sand is 10 feet high, the top of the conveyor is 6feet above the top of the pile, and sand is falling onto the top of the pile at the rate of 20 cubic feet per minute. Sandy expects sand to be added to the pile at that rate all afternoon.

(i) Formulate at least three mathematical questions arising from the Growing Sand Pile situation that could be answered from the information given.(A mathematical question is one that can be answered (or at least addressed)using mathematical tools and methods. A function that describes or models a situation is one of the mathematical tools often used to answer a mathematical question.)

(ii) Sandy would like to know whether the top of the sand pile will reach the conveyor before his shift ends at 4:30 PM. Explain why Sandy might be concerned about this question.

(iii) What two variables are involved in the question Sandy is concerned about in part (ii)? Which of these variables should be considered the independent variable? Explain why.Which of these variables should be considered the dependent variable? Explain why.

(iv) Find an explicit equation for the function that relates the variables you identified in (iii).

(v) Use the function you devised in (iv) to answer the question Sandy is concerned about. As this survey software does not have an easy-to-use formula editor, the only thing you need put here is your numerical answer to part (v). Your full answer to this question should be neatly written out on your homework to be handed to your instructor. Please give clear and concise reasons for each part of your answer.

To have your homework score updated please correctly type in your 9 digit student id number. (1)

Please enter your numerical answer to part (v) here (2)

APPENDIX J: STUDY INSTRUMENT AND CONSENT FORM

Q1 **Consent to Participate in a Research Study**
Colorado State University

TITLE OF STUDY: A mixed methods explanatory study of the failure/drop rate of freshman STEM calculus students.
Principal Investigator: Gene Gloeckner, School of Education CSU, Ph.D., gene.gloeckner@colostate.edu
CO-Principal Investigator: Mary Worthley, School of Education CSU, Graduate student, mary.worthley@colostate.edu

WHY AM I BEING INVITED TO TAKE PART IN THIS RESEARCH? The purpose of the study is to examine factors that influence student success in Math 160. You are invited to participate as you are a studying a freshman course in calculus.

WHO IS DOING THE STUDY? This research is part of a doctoral dissertation.

WHAT IS THE PURPOSE OF THIS STUDY? The purpose of the study is to examine factors that influence student success in a freshman course in calculus.

WHERE IS THE STUDY GOING TO TAKE PLACE? This survey will be conducted on-line. This on-line survey should be short and take between 10 - 20 minutes to complete.

WHAT WILL I BE ASKED TO DO? Complete this survey. This survey asks questions relating to your study strategies and motivation.

WHAT ARE THE POSSIBLE RISKS DISCOMFORTS? There are no known risks associated with participating in this research. It is not possible to identify all potential risks in research procedures, but the researcher(s) have taken reasonable safeguards to minimize any known and potential, but unknown, risks.

ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY? There are no direct benefits to you personally. There is an anticipated benefit to future students of the course, as it is hoped the course will improve from your feedback.

DO I HAVE TO TAKE PART IN THE STUDY? Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.
WHO WILL SEE THE INFORMATION THAT I GIVE? We will keep private all research records that identify you, to the extent allowed by law.

Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from your research records and these two things will be stored in different places under lock and key.

WILL I RECEIVE ANY COMPENSATION FOR TAKING PART IN THIS STUDY? If you complete this survey it will count as one homework score. If you choose to opt out of completing the survey an alternative homework question will be assigned by you instructor that should take an equivalent amount of time for you to complete.

WHAT IF I HAVE QUESTIONS? If you have questions about the study, then please contact the investigator, Mary Worthley at mary.worthley@colostate.edu before you complete the survey. If you have any questions about your rights as a volunteer in this research, contact Janell Barker, Human Research Administrator at 970-491-1655. We will give you a copy of this consent form to take with you.

This consent form was approved by the CSU Institutional Review Board for the protection of human subjects in research on 15th July, 2012.

WHAT ELSE DO I NEED TO KNOW? Please select the appropriate option below. Selecting either (or both) of the first two options indicates you are willing to participate in this survey. Selecting the last indicates you are not willing to participate and will do the allocated homework problem instead. Entering your correct student id acknowledges that you have read the information stated. For points to be credited to your homework score please enter your 9 digit student ID number accurately.

- ❑ I have read and understood the above and consent to participate in this research. My student id is: (1) ____________________
- ❑ I have read and understood the above and consent to allow access to this data (with any personal identification data removed) for other studies. (2)
- ❑ I do not wish to participate and will do the assigned homework problem instead. (3)

If I do not wish to participat... Is Selected, Then Skip To End of Survey

Q2 The following questions ask about your motivation for, and attitudes about, this class. Remember there are no right or wrong answers, just answer as accurately as possible. Use the scale below to answer the questions using the prompt that best describes you.

	never true of me (1)	**rarely true of me (2)**	**more often not true of me than true (3)**	**more often true of me than not (4)**	**frequently true of me (5)**	**always true of me (6)**
If I study in appropriate ways, then I will be able to learn the material in this course. (1)	❍	❍	❍	❍	❍	❍
When I take a test I think about how poorly I am doing compared with other students. (2)	❍	❍	❍	❍	❍	❍
I believe I will receive an excellent grade in this class. (3)	❍	❍	❍	❍	❍	❍
I'm certain I can understand the most difficult material presented in the readings for this course. (4)	❍	❍	❍	❍	❍	❍
When I take a test I think about items on other parts of the test I can't answer. (5)	❍	❍	❍	❍	❍	❍
It is my own fault if I don't learn the material in this course. (6)	❍	❍	❍	❍	❍	❍

	never true of me (1)	rarely true of me (2)	more often not true of me than true (3)	more often true of me than not (4)	frequently true of me (5)	always true of me (6)
I'm confident I can learn the basic concepts taught in this class. (7)	❍	❍	❍	❍	❍	❍
When I take tests I think of the consequences of failing. (8)	❍	❍	❍	❍	❍	❍
I'm confident I can understand the most complex material presented by the instructor in this course. (9)	❍	❍	❍	❍	❍	❍
If I try hard enough, then I will understand the course material. (10)	❍	❍	❍	❍	❍	❍
I have an uneasy, upset feeling when I take an exam. (11)	❍	❍	❍	❍	❍	❍
I'm confident I can do an excellent job on the assignments and tests in the is course. (12)	❍	❍	❍	❍	❍	❍
I expect to do well in this class. (13)	❍	❍	❍	❍	❍	❍
If I don't understand the course material, it is because I didn't try hard enough. (14)	❍	❍	❍	❍	❍	❍
I feel my heart beating fast when I take an exam. (15)	❍	❍	❍	❍	❍	❍
I'm certain I can master the skills being taught in this class. (16)	❍	❍	❍	❍	❍	❍
Considering the difficulty of this course, the instructor, and my skills, I think I will do well in this class. (17)	❍	❍	❍	❍	❍	❍

Q3 The following questions ask about your learning strategies and study skills for this class. Again, there are no right or wrong answers. Answer the questions about how you study in this class as accurately as possible. Use the scale below to answer the questions using the prompt that best describes you.

	never true of me (1)	**rarely true of me (2)**	**more often not true of me than true (3)**	**more often true of me than not (4)**	**frequently true of me (5)**	**always true of me (6)**
When I study the readings for this course, I outline the material to help me organize my thoughts. (1)	❍	❍	❍	❍	❍	❍
I usually study in a place where I can concentrate on my course work. (2)	❍	❍	❍	❍	❍	❍
I often feel so lazy or bored when I study for this class that I quit before I finish what I planned to do. (3)	❍	❍	❍	❍	❍	❍
When I study for this class, I practice saying the material to myself over and over. (4)	❍	❍	❍	❍	❍	❍
Even if I have trouble learning the material in this class, I try to do the work on my own, without help from anyone. (5)	❍	❍	❍	❍	❍	❍
When I study for this course, I go through the readings and my class notes and try to find the most important ideas. (6)	❍	❍	❍	❍	❍	❍
I make good use of my study time for this course. (7)	❍	❍	❍	❍	❍	❍
When studying for this course, I read my class notes and the course readings over and over again. (8)	❍	❍	❍	❍	❍	❍
I work hard to do well in this class even if I don't like what we are doing. (9)	❍	❍	❍	❍	❍	❍

	never true of me (1)	rarely true of me (2)	more often not true of me than true (3)	more often true of me than not (4)	frequently true of me (5)	always true of me (6)
I make simple charts, diagrams, or tables to help me organize course material. (10)	❍	❍	❍	❍	❍	❍
I find it hard to stick to a study schedule. (11)	❍	❍	❍	❍	❍	❍
When I study for this class, I pull together information from different sources, such as lectures, readings, and discussions. (12)	❍	❍	❍	❍	❍	❍
I ask the instructor to clarify concepts I don't understand well. (13)	❍	❍	❍	❍	❍	❍
I memorize key words to remind me of important concepts in this class. (14)	❍	❍	❍	❍	❍	❍
When course work is difficult, I either give up or only study the easy parts. (15)	❍	❍	❍	❍	❍	❍
I try to relate ideas in this subject to those in other courses whenever possible. (16)	❍	❍	❍	❍	❍	❍
When I study for this course, I go over my class notes and make an outline of important concepts. (17)	❍	❍	❍	❍	❍	❍
When reading for this class, I try to relate the material to what I already know. (18)	❍	❍	❍	❍	❍	❍
I have a regular place set aside for studying. (19)	❍	❍	❍	❍	❍	❍

	never true of me (1)	rarely true of me (2)	more often not true of me than true (3)	more often true of me than not (4)	frequently true of me (5)	always true of me (6)
When I study for this course, I write brief summaries or the main ideas from the readings and my class notes. (20)	❍	❍	❍	❍	❍	❍
When I can't understand the material in this course, I ask another student in this class for help. (21)	❍	❍	❍	❍	❍	❍
I try to understand the material in this class by making connections between the readings and the concepts from the lectures. (22)	❍	❍	❍	❍	❍	❍
I make sure that I keep up with the weekly readings and assignments for this course. (23)	❍	❍	❍	❍	❍	❍
I make lists of important items for this course and memorize the list. (24)	❍	❍	❍	❍	❍	❍
I attend this class regularly. (25)	❍	❍	❍	❍	❍	❍
Even when course materials are dull and uninteresting, I manage to keep working until I finish. (26)	❍	❍	❍	❍	❍	❍
I try to identify students in this class whom I can ask for help if necessary. (27)	❍	❍	❍	❍	❍	❍
I often find that I don't spend very much time on this course because of other activities. (28)	❍	❍	❍	❍	❍	❍
I rarely find time to review my notes or readings before an exam. (29)	❍	❍	❍	❍	❍	❍

	never true of me (1)	**rarely true of me (2)**	**more often not true of me than true (3)**	**more often true of me than not (4)**	**frequently true of me (5)**	**always true of me (6)**
I try to apply ideas from course readings in other class activities such as lecture and discussion. (30)	❍	❍	❍	❍	❍	❍

APPENDIX K: INTERVIEW EMAIL INVITATION

Hi.
I am a doctoral student who is studying factors that influence student success in Math 160. As such I am contacting students who have studied Math 160 within the past five years, as I am interested in hearing their experiences of this course, regardless of whether or not they passed or failed it. If you are interested in helping me then please read on, otherwise thank you for your time.

There is one of two ways you can help me:
1. By attending a short interview. If you wish to see a copy of the consent form and questions I intend to ask then please follow the following link: {link entered here}
   Password: Math160
2. Alternatively by sending to me a short written response to the questions I would have asked in an interview. To do this please follow the following link: {link entered here}
   Password: Math160

If you have time to attend an interview then please let me know when this would be convenient for you between the following dates: 8/7/2012 – 9/7/2012. Please contact me via email at mary.worthley@colostate.edu. The interview will take place in a public place, like a coffee shop or an outside table on the CSU campus (weather permitting). The cost of a cup of coffee, tea or soda will be covered. It is expected the interview will take about 30 minutes.

My study has been approved by the Internal Review board on July 15, 2012. If you have questions about the study, then please contact the investigator, Mary Worthley at mary.worthley@colostate.edu before you complete the survey.

If you have any questions about your rights as a volunteer in this research, contact please Janell Barker, Human Research Administrator, CSU, at 970-491-1655.

Thank you for your attention.

Co-Principal Investigator: Mary Worthley
School of Education, CSU
mary.worthley@colostate.edu

Principal Investigator: Gene Gloeckner,
School of Education CSU, Ph.D.,
gene.gloeckner@colostate.edu

APPENDIX L: INTERVIEW QUESTIONS AND CONSENT FORM.

Q1 **Consent to Participate in a Research Study**
Colorado State University

TITLE OF STUDY: A mixed methods explanatory study of the failure /drop rate for freshman STEM calculus students.

Principal Investigator: Gene Gloeckner, School of Education CSU, Ph.D., gene.gloeckner@colostate.edu

CO-Principal Investigator: Mary Worthley, School of Education CSU, Graduate student, mary.worthley@colostate.edu

WHY AM I BEING INVITED TO TAKE PART IN THIS RESEARCH? The purpose of the study is to examine factors that influence student success in Math 160. You are invited to participate as someone who is studying, or has studied, a freshman course in calculus.

WHO IS DOING THE STUDY? This research is part of a doctoral dissertation.

WHAT IS THE PURPOSE OF THIS STUDY? The purpose of the study is to examine factors that influence student success in a freshman course in calculus.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST? If you have chosen to be interviewed then the interviews will take place in a public place, like a coffee shop or an outside table on the CSU campus (weather permitting). If you have chosen to respond to questions in writing then this will take place on-line. It is expected the interview or written response will take about 30 minutes.

WHAT WILL I BE ASKED TO DO? Respond to interview questions. During the interview you will be asked questions about your study routine for Math 160.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS? None I can foresee. It is not possible to identify all potential risks in research procedures, but the researcher(s) have taken reasonable safeguards to minimize any known and potential, but unknown, risks.

ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY? If you are a currently struggling student in Math 160 you may find out what different options are out there to help. There is an anticipated benefit to future students of the course, as it is expected the course will improve from your feedback.

DO I HAVE TO TAKE PART IN THE STUDY? Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

WHO WILL SEE THE INFORMATION THAT I GIVE? We will keep private all research records that identify you, to the extent allowed by law.

Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from your research records and these two things will be stored in different places under lock and key. Your identity/record of receiving compensation (NOT your data) may be made available to CSU officials for financial audits.

CAN MY TAKING PART IN THE STUDY END EARLY? Only at your request.

WILL I RECEIVE ANY COMPENSATION FOR TAKING PART IN THIS STUDY? If you attend an interview then the cost of a cup of coffee, tea or soda will be covered.

WHAT IF I HAVE QUESTIONS? If you have questions about the study, then please contact the investigator, Mary Worthley at mary.worthley@colostate.edu before you complete the survey.

If you have any questions about your rights as a volunteer in this research, contact Janell Barker, Human Research Administrator at 970-491-1655. We will give you a copy of this consent form to take with you.

This consent form was approved by the CSU Institutional Review Board for the protection of human subjects in research on 15th July, 2012.

WHAT ELSE DO I NEED TO KNOW? Interviews: The interview will be recorded and transcribed for research purposes. If you wish for a copy of the transcription then please let the interviewer know and a copy will be forwarded to you via email. Please feel free to annotate this transcript and return it to the investigator. Written responses: These are completely anonymous, unless you consent for me to have access to your grade details.

- ❍ I have read and understood the above and consent to anonymously complete a written response. (1)
- ❍ I have read and understood the above and consent to complete a written response and the researcher accessing my grade information. (Please enter CSU ID below.) (2)
  ____
- ❍ I just wanted to see what the questions looked like. (3)

Q2 Please select your appropriate Math 160 result

- ❍ I passed first time though with the grade I required. (1)
- ❍ I passed Math 160 but needed to repeat it to get the grade I required. (2)
- ❍ I failed Math 160, but eventually passed it with the grade I required. (3)
- ❍ I failed Math 160 and I am still trying to pass it. (4)

- Other. (5)

Answer If Please select your appropriate Math 160 result Passed first time though with grade required. Is Selected

Q3 To what do you attribute your success in achieving the grade you required in Math 160?(For example: What study techniques did you use? How much time did you spend on this subject - and how did you spend this time? Did you have an other all study plan? Did you have a study buddy? Or anything else you believe to be relevant.)

Answer If Please select your appropriate Math 160 result Passed Math 160 but needed to repeat it to get grade required. Is Selected Or Please select your appropriate Math 160 result Failed Math 160, but eventually passed it with required grade. Is Selected

Q4 What do you think went wrong the time you did not get the grade you required, and what went right the time you passed with the grade you did require in Math 160?
Answer If Please select your appropriate Math 160 result Failed Math 160 and still trying to pass it. Is Selected

Q5 What do you think went wrong? In particular: What was you expectation of this math course? What was your expectation for studying this course? What was your understanding of the level of work required? Or anything else you believe to be relevant.

Answer If Please select your appropriate Math 160 result Other. Is Selected

Q6 Please briefly describe your experience of the Math 160 course(s) you took.
Answer If Please select your appropriate Math 160 result Failed Math 160, but eventually passed it with required grade. Is Selected Or Please select your appropriate Math 160 result Failed Math 160 and still trying to pass it. Is Selected Or Please select your appropriate Math 160 result Other. Is Selected

Q7 What factors did you consider when choosing to repeat/drop this course?

Q8 Which best describes your decision to come to CSU

- You chose your major and then CSU. (1)
- You chose CSU and the your major. (2)

Answer If Consent to Participate in a Research Study<o:p></o:p> Co... I have read and understood the above and consent to anonymously complete a written response. Is Selected
Q9 In the semester you (first) took Math 160, what college were you attached to?

- School of Engineering (1)
- School of Natural Sciences (2)
- Intra University (3)
- Other (4)

Q10 If you needed to repeat other courses you took in the same semester as the semester you (first) took Math 160, then how many (not including Math 160) did you need to repeat?

- I passed everything with the grade I needed. (1)
- 1 (2)
- 2 (3)
- More than 2 (4)

APPENDIX M: RESULTS TABLES.

Phase One: Historical Data Fall 2007 – Fall 2011 Descriptive Statistics

TableM1.
Variable Correlations.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Grade	-											
2. PACe	.38**	-										
	n=2296											
3. CCHE	.38**	.46**	-									
	n=2402	*n*=1947										
4. ACT	.33**	.51**	.56**	-								
Math	n=2366	*n*=1885	*n*=2192									
5. ACT	.28**	.37**	.68**	.47**	-							
Eng	*n*=2366	*n*=1885	*n*=2192	*n*=2366								
6. ACT	.17**	.23**	.63**	.37**	.62**	-						
Read	n=2366	*n*=1885	*n*=2192	*n*=2366	*n*=2366							
7. ACT	.36**	.40**	72**	.49**	.94**	.63**	-					
Write	*n*=427	*n*=361	*n*=410	*n*=427	*n*=427	*n*=427						
8. ACT	.30	.43**	.77**	.70**	.83**	.83**	.81**	-				
Comp	*n*=2366	*n*=1885	*n*=2192	*n*=2366	*n*=2366	*n*=2366	*n*=427					
9. SAT	.34**	.49**	.59**	.68**	.48**	.41**	.38**	.63**	-			
Math	*n*=1026	*n*=838	*n*=941	*n*=774	*n*=774	*n*=774	*n*=202	*n*=774				
10. SAT	.18**	.35**	.64**	.40**	.65**	.69**	.63**	.70**	.48**	-		
Reading	*n*=1026	*n*=838	*n*=941	*n*=774	*n*=774	*n*=774	*n*=202	*n*=774	*n*=1026			
11. SAT	.23**	.34**	.63**	.42**	.69**	.59**	.72**	.68**	.48**	.76**	-	
Writing	*n*=956	*n*=810	*n*=895	*n*=731	*n*=731	*n*=731	*n*=202	*n*=731	*n*=956	*n*=956		
12. SAT	.29**	.47**	.71**	.61**	.66**	.65**	.62**	.78**	.81**	.90**	.74**	-
Com	*n*=1026	*n*=838	*n*=941	*n*=774	*n*=774	*n*=774	*n*=202	*n=774*	*n*=1026	*n*=1026	*n*=956	

** $p < .01$

Table M2.
Data for Figures 1 & 4

Period	**Passed**	**Withdrew**	**Only failed M160**	**One other F**	**2 or more other F's**
fall					
2007	298	63	42	24	26
2008	283	72	55	18	10
2009	336	68	47	19	12
2010	377	71	39	14	16
2011	318	41	42	17	11
spring					
2008	170	42	23	18	11
2009	169	58	27	22	7
2010	157	39	29	12	10
2011	163	32	39	16	11

Table M3
Fall Pie Chart Data

fall	Total	D or F	F only
Total	2004	674	392
Engineering	1095	283	137
Intra Uni	475	239	165
Nat Sci	328	117	66
Other	106	35	24

Table M4.
Spring Pie Chart Data

spring	Total	D or F	F
Total	884	336	225
Engineering	303	120	73
Intra Uni	370	140	100
Nat Sci	156	58	41
Other	55	18	11

Table *M5.*
Average Percentage Fail Rates by Section

fall	1 pm	Large 2pm class	Small 2pm class	3 pm	4 pm	8 am	Large 9am class	Small 9am class	10 am	11 am	12 noon
Average %F	20.94	12.93	16.55	19.61	18.23	15.91	15.2	18.07	30.42	36.67	21.23
Weighted Average %F	20.93	16.44	15.56	19.71	18.25	15.69	14.98	17.74	30.81	34.09	20.1
Range %F	13.79	11.97	22.54	25.04	7.52	10.91	8.41	6.72	22.15	13.33	20
Average %D	16.23	14.53	18.42	11.08	17.74	11.52	12.91	14.5	14.95	15	10
Weighted Average %D	15.81	14.82	17.78	10.22	17.52	11.11	13.04	14.52	14.65	14.77	9.79
Range %D	19.12	16.64	27.64	20	26.3	16.11	4.73	0.42	28.57	10	12.14
Average %DF	37.16	31.46	34.97	30.69	35.97	27.43	28.12	32.56	45.37	51.67	31.23
Weighted Average %DF	36.74	31.25	33.33	29.93	35.77	26.8	28.02	32.26	45.46	48.86	29.9
Range %DF	21.81	11.7	41.88	33.44	28.52	23.31	8.61	6.3	33.08	3.33	31.43

spring	1 pm	Large 2pm class	Small 2pm class	3 pm	4 pm	8 am	9 am	10 am	11 am	12 noon
Average %F	21.47	27.98	30.32	31.86	45.45	29.62	25.14	20.19	28.48	28.81
Weighted Average %F	21.43	29.06	30.61	30.89	45.45	29.73	25.21	18.18	28.9	27.07
Range %F	16.52	7.19	20.05	45.47	0	5.91	22.15	23.33	14.72	32.37
Average %D	9.67	15.87	14.66	8.1	27.27	12.36	11.93	15.75	11.85	16.41
Weighted Average %D	9.82	16.24	16.33	8.13	27.27	12.16	11.76	15.58	11.41	16.54
Range %D	10.71	2.47	28.57	7.5	0	9.7	17.46	3.91	14.02	31.45
Average %DF	31.14	43.85	44.97	39.95	72.73	41.98	37.02	35.94	40.33	45.22
Weighted Average %DF	31.25	45.3	46.94	39.02	72.73	41.89	36.97	33.77	40.3	43.61
Range %DF	21.43	9.66	38.45	49.28	0	5.54	31.84	26.67	22.75	53.81

Phase Two: Descriptive statistics for Fall 2012 for MATH 160 sections analyzed.

Table M6.
Variables Means, Standard Deviations and Skew.

Variable	Independent/ Dependent	Type	N	Mean	SD	Skew
Exam1	D	Scale	244	63.56	18.51	-0.46
CCHE	I	Scale	221	121.02	9.80	-0.43
Average study	I	Scale	150	2.5	4.20	5.66
Ease of Math	1	Scale	150	2.83	.65	.773
School quality	I	Scale	150	2.89	0.89	0.05
Prior Calc Experience	I	Scale	150	2.74	1.17	0.19
Control	I	Scale	176	17.51	4.16	-1.84
Test anxiety	I	Scale	176	17.84	6.317	-0.43
Self Efficacy	I	Scale	176	32.01	8.50	-1.37
Organization	I	Scale	176	13.77	4.06	-0.68
Effort Regulation	I	Scale	176	18.58	2.86	-0.18
Aggregate PACe placement scores	I	Scale	185	30.73	9.62	-0.30
Student persistence	I	Dichoto mous	453	.85	.36	
Listwise			77			

Table M7.
Number of Students From Fall Semester 2009, 2010, and 2011 Contacted for Interviews via email.

College Year	Engineering	Intra University	Natural Sciences	Other	Total (% of # completed)
2009	194	72	63	17	346 (83.57)
2010	225	93	92	26	436 (97.76)
2011	221	88	57	21	387 (99.74)

Table M8.
Attributes of MATH 160 Students Who Were Interviewed for the Study.

		2009	2010	2011	Trad/Non-Trad	Repeated
Engineering					1T 1N	1
	Passed	1	0	1		
	Failed	0	0	0		
Intra University					2T 2N	2
	Passed	1	1	0		
	Failed	0	1	1		
Natural Sciences					3T 3N	2
	Passed	0	4	1		
	Failed	0	0	1		
Other					1N	
	Passed	1	0	0		
	Failed	0	0	0		
TOTAL		3	6	4		

Table M9.
Attributes of MATH 160 Students Who Responded to Survey

		2009	2010	2011
Engineering				
	Passed	3	5	5
	Failed	1	0	0
Intra University				
	Passed	0	2	1
	Failed	1	0	1
Natural Sciences				
	Passed	2	2	1
	Failed	0	0	1
Other				
	Passed	0	1	0
	Failed	0	0	1
TOTAL		7	10	10