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The Influences of Calculus I on Engineering Student Persistence

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THE INFLUENCES OF CALCULUS I ON ENGINEERING

STUDENT PERSISTENCE

by

Amie Baisley

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ABSTRACT

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The retention rates for engineering students are consistently reported around 50%, where many students leave the degree program within their first two years. The pre-engineering courses have been documented as major reasons students leave engineering and these include the required math and science courses. Calculus I is the first major math requirement for all engineering students and can often be the stopping point for most students to switch majors or leave an institution altogether. Another important factor for student persistence is allowing them to develop a sense of belonging especially during their first year at a university. Sense of belonging can have major impacts on student persistence along with academic performance. The purpose of this study is to understand the social and academic influences that impact engineering students during their time in Calculus I.

A mixed method research study was performed that included a quantitative analysis on 13 years of engineering student math data and a qualitative analysis that included 10 student interviews. In both strands of the analysis, there was data from persisting students, which includes students still in engineering, and leaving students, which include students that have left engineering after taking Calculus I. The results were synthesized to determine how students integrate both academically and socially during their experience in Calculus I. The results revealed that both persisters and leavers feel no social integration into engineering during their time in Calculus I. However, persisters did gain some academic integration into engineering and had more positive academic experiences than leavers during that course. From these results, recommendations are offered to create a better experience for engineering students during their time in Calculus I.

(160 pages)

PUBLIC ABSTRACT

The Influences of Calculus I on Engineering

Student Persistence

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About half of the students that are declared engineering majors end up leaving engineering within their first two years at the university. This happens following the required math and science courses that these students must take before getting into the technical engineering coursework. There are two systems that students must be a part of at the university to feel comfortable and have the desire to continue on in their degree. These include the academic system and the social system. The experiences engineering students have during their first required math course, Calculus I, is likely not promoting integration into these two systems.

This study analyzed student grade data from Calculus I for trends about student persistence in engineering, along with interviewing students about their experience in Calculus I. These analyses revealed that students do not integrate into the social system of engineering during this course and only persisting students show some positive signs of integration into the academic system. This indicates that there are many gaps in the engineering student experience during their early career that can help these students feel like they belong in engineering and want to stay. Fortunately, there are many areas that can easily be remedied to provide a better social and academic experience in Calculus I to help increase the number of students that remain in engineering until graduation.

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CHAPTER 1

INTRODUCTION

Engineering student retention has been a major concern for higher education institutions for many decades now. The National Academy for Engineering (NAE) has stated that only 40-60% of students who start in an engineering program will graduate with an engineering degree, and if the population is broken down further for women and minorities, the percentage gets even lower (National Academy of Engineering, 2005). Further, the gap between industry needs and qualified engineering graduates continues to increase. The current number of graduating engineers in the U.S. is still not enough to meet today's workforce demands nor can it keep up with the numbers of graduates in other countries (Geisinger & Raman, 2013; Moses et. al., 2011). There are countless reasons given to try to explain this low retention number including factors that range from student issues to institutional issues, but one of the leading causes has been attributed to the coursework that engineering students are required to take early on in their program (Ohland, Yuhasz, & Sill, 2004; Guner, 2013; Middleton et. al., 2015). These courses include a series of math courses typically made up of 2-3 calculus courses depending on engineering degree type, a linear algebra course, a differential equations course, and a series of science courses.

The calculus courses are required of engineering students typically upon entrance to college if they want to graduate with a degree in four years. This entire series is normally completed during a student's first two years in an engineering program. Research has shown that these calculus courses, specifically Calculus I, are an issue and has classified them as barrier courses for many engineering students (Ohland et. al., 2004; Daempfle, 2002; Rask, 2010). A barrier course is a course known to be challenging and potentially a stopping point for many students, but it is required of all students to progress forward in the degree (Suresh, 2007). In engineering, students are taking these barrier math courses very early on in their program, often prior to getting involved in actual engineering curriculum. They are also, unfortunately, part of the reason a student decides to leave the engineering program. However, in contrast, if an engineering student can successfully complete these prerequisite math courses and persist through their first two years, then the likelihood they will graduate in engineering increases significantly (Budny, Bjedov, & Lebold, 1997; Chen, 2013; Middleton et. al., 2015).

It has also been stated in the literature that a major factor common to all of higher education persistence is the development of student's sense of belonging (Hurtado & Carter, 1997; Karp, Hughes, & O'Gara, 2008; Hausmann, Ye, Schofield, & Woods, 2009; Aguirre-Covarrubias, 2013). Sense of belonging is defined as becoming integrated into the university both socially and academically. However, in engineering developing this sense of belonging can be challenging for a student initially since the calculus courses are often taken through a separate math department creating a disconnect from the engineering program. As a result, the students find it challenging to understand how these ideas fit in with the engineering program. A student's first year in college is the most important time to try to develop the students' sense of belonging (Tinto, 1993), but for engineering students this responsibility falls to general education and prerequisite courses to do this. There has been a push in engineering education to offer a freshman engineering course that incorporate these math and science concepts to try to increase this integration early on, but it is still far from the norm in engineering education (Venable, McConnel, & Stiller, 1995; Pines, Nowak, Alnajjar, Gould, & Bernardete, 2002).

Much of the literature on this topic has focused on two routes to try to understand the problem. The first has been to determine the predictors of successful completion of these prerequisite math courses using pre-college variables like SAT/ACT score, high school GPA, and math placement score (Felder, Mohr, Dietz, & Baker-Ward, 1994; Bernold, Spurlin, & Anson, 2007; Moses et. al. , 2011). The second focus has been on using the results of these math courses to determine how they affect engineering retention longterm (Litzler & Young, 2012; Budny et. al., 1997; Middleton et. al., 2015, 2015). However, there has not been substantial research into the actual calculus courses and how students perceive those courses relative to their engineering degree and their decision to persist in the major. This project will investigate the influences of Calculus I on engineering student persistence from both the college and student perspective.

1.1 Theoretical Framework

This project used Vincent Tinto's Institutional Departure Model as the theoretical framework (Tinto, 1993). This longitudinal student departure model considers various factors that influence a student's decision to stay or leave an institution. These factors include pre-college entry variables, external influences, the academic system, and the social system. Through these stimuli, a student must integrate into the institution both socially and academically; otherwise they will depart. Tinto emphasizes that both social and academic integration are necessary for persistence (Tinto, 1993).

Tinto's model was chosen for this study because it comes from a sociological perspective that looks at the external influences on a student rather than the psychology of an individual student. This is done through considering both academics and social interactions that take place in college. Also, the inclusion of academic performance, such as grades which significantly impact a student's progress through the engineering degree program, is essential to consider for departure of engineering students. After reviewing the most common student departure models, Tinto's was chosen as the one that involves all the constructs that are important to engineering students and provides the most valuable framework for this problem to offer recommendations at an institutional level.

The term integration has recently been used interchangeably with sense of belonging and has been described as: "Integration is used to explain the extent to which students come to share the attitudes and beliefs of their peers and faculty and the extent to which students adhere to the structural rules and requirements of that institution-the institutional culture" (Wolf-Wendel, Ward, & Kinzie, 2009, p. 414). Further, the concepts of academic and social integration have been defined in the literature as:

> Social integration refers to students' perceptions of interactions with the peer group, faculty, and staff at the institution as well as involvement in extra- and co-curricular activities. Academic integration refers to perceptions of the experiences in the formal and informal academic system resulting from interactions with faculty, staff, and students inside and outside the classroom settings that enhance the intellectual development of the student (Wolf-Wendel et. al., 2009, p. 415).

This study will focus on these two key constructs of academic and social integration as highlighted in Figure 1.

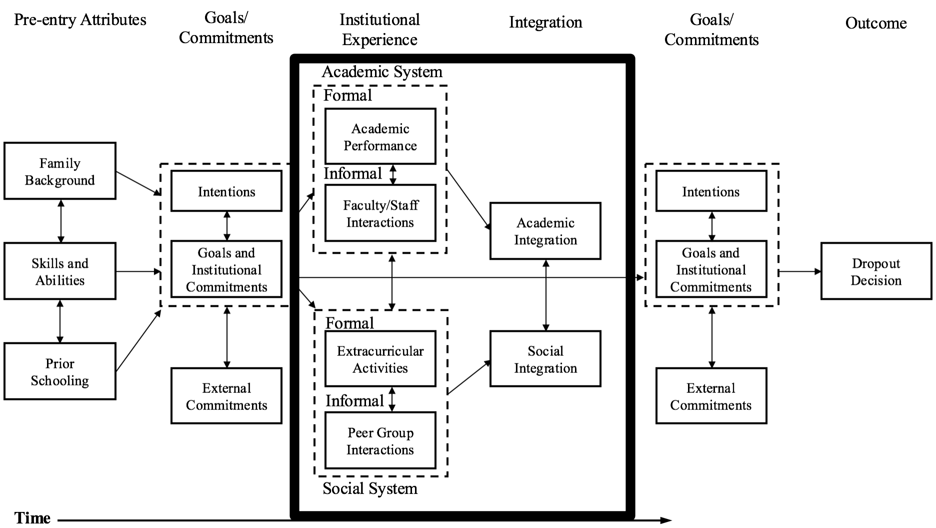

Figure 1. Vincent Tinto's Institutional Departure Model (Tinto, 1993, p. 114)

The focus will be on how the constructs of social and academic integration are developed in Calculus I by engineering students. This integration will be evaluated through different sources of data to determine if positive development of either construct has taken place as a result of the Calculus I. The development is considered positive if that experience has helped the student integrate into engineering and will be considered negative if it does not help or hurts a student's integration into engineering. For this study, *academic integration* will be defined as the extent of a student's involvement in their academic endeavors. This will include both academic performance that can be quantified and the amount of interaction with faculty and staff about academic topics relative to a student's degree. *Social integration* will be defined as the extent of a student to be engaged and interact with the engineering community outside of the formal academic environment. This includes interactions with peers, faculty, and staff outside of formal academic topics and involvement in extracurricular activities related to engineering. These constructs will be assessed for two different groups of students: the persisters and the leavers. A *persister* is a student who has graduated from or is still registered in an engineering degree program since taking Calculus I. A *leaver* is a student who was a declared engineering major when they took Calculus I but has since switched out of engineering to another major or left the institution.

1.2 Methodology

The study is based on Tinto's Institutional Departure Model focusing on academic and social integration of engineering students during their time in Calculus I. The researcher is positioned using a pragmatic lens with the intent to use this research to inform practice. This lens creates the need to understand the problem from different perspectives and various sources of data. As a result, there is both quantitative and qualitative data that are of relevance to understand these constructs. This study will follow a *partially mixed sequential dominant status* mixed method research design (Johnson & Onwuegbuzie, 2004; Leech & Onwuegbuzie, 2009). First quantitative data collection and analysis will take place and then used to help create questions to use for the qualitative data collection and analysis. The results will emphasize the qualitative results which will provide a deeper and richer understanding of the issue further than the findings from the quantitative analysis.

The quantitative data contains 13 years of calculus course data for students that were declared engineering majors at the time they took the Calculus I course. The data includes the student's current major (they could have switched out of engineering since taking the course), the grade received in the course, the number of retakes, admission variables, and demographic variables for all the calculus courses the student took at a major research university in the Rocky Mountain region. The data was analyzed using logistic regression analysis to create a model that includes only the most significant factors that affect persistence in engineering. The data is broken into two groups with models created for each. The first group contains all students that took Calculus I at the university of the study, where the persisters are those that are still currently registered or graduated in engineering, and the leavers are all other students. The second group contains only students that have graduated, where the persisters are those that graduated in engineering, and the leavers are those that graduated in a major other than engineering. The models will indicate the variables that are statistically significant for persistence in engineering.

The next part of the project includes the qualitative data collection and analysis that dove deeper into the actual student experience in Calculus I. This was completed using semi-structured interviews with 10 participants. The participants were recruited from the students that took Calculus I during the spring or fall of 2017. The study recruited six persisting students still in engineering and four leavers who are now in a different major outside of engineering. The interview questions focused on the student's social and academic integration into engineering during their time in Calculus I. The interviews were analyzed using both a priori and descriptive codes. This allowed the development of a codebook that includes themes found in previous literature of Tinto's framework and any emergent themes specific to this study. The codes were then grouped into major themes reported in the results. One member-checking session and one analyst triangulation session were used to validate the results. The member-checking session was with the students that participated in the interviews to ensure that their stories and feelings were portrayed correctly. The analyst triangulation was completed with the advising staff of the College of Engineering who are familiar with the retention problem in engineering and the issues that the calculus courses present for student persistence. Once all the analysis was complete, the results from both methods were used to answer the hypothesis and research questions of the study. The results were also integrated together to answer the final research question that includes all of the formal and informal academic/social integration constructs in Tinto's Institutional Departure Model.

1.3 Purpose of the Study

The purpose of this study was to understand the influence that Calculus I had on an engineering students' academic and social integration into the degree program. This study looked at the extent of the problem from the college level using quantitative methods with longitudinal data. These results confirmed the claims that have been made in the literature about how significant these courses are on engineering retention. Then an in-depth look was taken to share actual student experiences in Calculus I. The results uncover many of the reasons for varying student performance in Calculus I and reasons for why engineering students leave the major. The use of both a breadth and depth approach is important for understanding if students develop any academic or social integration into engineering from Calculus I to be able to then use this information to begin to inform curriculum change.

1.4 Hypothesis and Research Questions

The study tested the following hypothesis in the quantitative portion:

1. The academic integration of an engineering student as measured by academic performance in Calculus I is correlated with their persistence in the engineering degree program.

The qualitative portion of the study answered the following research questions:

1. How does an engineering student's academic integration develop during Calculus I?
2. How does an engineering student's social integration develop during Calculus I?
3. In what ways does social and academic integration differ for engineering persisters and leavers?

1.5 Significance of Study

This analysis provided useful and relevant information to the College of Engineering at the current research site. The results are also transferable to other similar engineering programs. The information provided the actual number of students that left the major following Calculus I and provided the student explanations as to why this is happening. The student perspective offered course related reasons that the College of Engineering can address in the future to provide a better experience. This work will also add to the current literature of engineering persistence by focusing in on Calculus I and the influences that course has on engineering student development. This project is also very timely as many engineering programs are reevaluating the math requirements of their program and the need to have them taught out of department since ABET EC2000 has been adapted and offered more flexibility to engineering programs (ABET Engineering Accreditation Commission, 2015). The results of this study provided evidence on this topic from the perspective of an engineering program that continues to require all math courses to be taken through a math department.

1.6 Assumptions of the Study

The assumptions of this study are primarily relevant to the qualitative analysis and choice of participants. It was assumed that the participants would be willing to share their experience in Calculus I whether it is positive or negative. The researcher also assumed that the selected participants who have left engineering would attribute some of their decision to leave the degree to Calculus I and be willing to talk about these reasons. Further, the researcher assumed that engineering programs would be interested in the results with the intent to make a curricular change at some level of the program.

1.7 Limitations of the Study

The limitations of this study include the use of students from a single research university in the Rocky Mountain region. The quantitative population may not be generalizable to the populations of other engineering programs because the selected university has a unique student population makeup influenced by the area's predominant religion. The statistical analysis was also limited by the available demographic variables that the researcher could obtain and within those, there is a substantial amount of data missing for some of the students. The qualitative population was small and may not be representative of the current institution's engineering population. The participation in this portion was completely voluntary and limited, so the participants were based on the students that were interested and a representative sample could not be created. The leavers were also selected from students who switched out from engineering but are still current students at the university in different majors, so this does not provide the perspective from a student who has completely left the university. A final limitation of the study is that Calculus I may not be the reason these students left engineering. This does not allow the study to fully represent the reality of all the reasons students may switch out of the major, as the focus is only on the environment of Calculus I.

1.8 Definition of Key Terms

Academic integration: the extent of a student's involvement in their academic endeavors. This will include both the (1) formal academic integration: academic performance that can be quantified and (2) informal academic integration: the amount of interaction with faculty and staff about academic topics relative to the student's degree.

Attrition: a student leaves their original degree program either for a different major or leaves the university entirely. The opposite of retention. Attrition data is used as a measure of program success in higher education.

Barrier course: a course that is often found challenging to many students and even a cause for students to stop progressing in their original degree due to failure or other issues from this course.

Leaver: a student who was declared an engineering major when they took Calculus I but has since switched out of engineering or left the institution.

Persistence: when a student stays in the same degree program from semester to semester with the goal to graduate from that program.

Persister: a student who has graduated from or is still registered in an engineering degree program.

Pre-professional program: the first 2 years of coursework for an engineering student that leads into the upper division engineering courses. Students must receive and maintain certain grades in all the required courses to be accepted into the professional program.

Professional program: the final 2 years of coursework for an engineering degree that focuses on the specific field of each major program.

Retaker: a student who has taken Calculus I more than one time.

Retention: a student stays in their original degree program. The opposite of attrition. Retention data was used as a measure of program success in higher education.

Social integration: the extent of a student to be engaged and interact with the engineering community outside of the formal academic environment. This includes (1) formal social integration: involvement in extracurricular activities related to their engineering major, and (2) informal social integration: interactions with peers and other engineering students.

CHAPTER 2

REVIEW OF THE LITERATURE

Attrition in education is both a serious and heavily studied issue, and the emphasis of the issue in higher education has created a substantial number of resources and even careers to try to understand retention rates, entrance scores, and even the creation of predictive models to try to address the problem. The magnitude of the problem is reported nationwide every year through the U.S. Department of Education's National Center for Education Statistics. The most recent statistics report that there were 2.2 million students that enrolled in college for the first time in fall 2018, and the average retention rate for students to graduate from their starting institution within 6 years is about 60 percent (McFarland et. al., 2018). These numbers represent an enormous loss in the number of students that continue on to graduate from higher education institutions. While there are numerous reasons that students leave college, there have been discipline specific studies and explanations developed that focus on the major issues that students face on their path to persisting through college. This literature review will focus on the attrition problem in the context of bachelor degree earning engineering students to understand what has been done and how it has been done. The review will first include retention studies specific to engineering majors and then the focus will be narrowed down to literature discussing the effects of the math requirements on engineering students. The next section will describe the available student departure models and then focus in on studies that have used Tinto's Institutional Departure Model as a theoretical framework. A review of the relevant different research methods used in engineering education research and how these methods have been used in similar studies to engineering persistence is in the final section. In this literature review, the background, context, and support for the current research study will be provided.

2.1 Undergraduate Engineering Student Persistence

The number of available engineering jobs is only continuing to increase and the need for qualified applicants is not going away, but the percent of college-bound students that enroll as an engineering major is only 9% of all bachelor degree enrolling students (Chen, 2013). Further, the engineering retention rate is consistently reported to be below the higher education national average at around 50 percent, which is placing a growing demand on the higher education system to keep and produce more engineers (Fortenberry, Sullivan, Jordan, & Knight, 2007; Ngambecki, Evangelou, Long, Ohland, & Ricco, 2010; Ohland et. al., 2004; Litzler & Young, 2012; Grose, 2008). This retention problem has been studied in depth and from a variety of perspectives as testified by the 50 paper review written by Geisinger and Raman (2013). There have been a variety of approaches used to understand engineering student retention including the use of predictive measures, affective measures, and a combination of both to try to understand why or predict if students will stay or leave an engineering degree program.

The use of predictive models has been a route to try to quantify the issue and look for students that are likely to succeed in the degree or fall into an at-risk category. The majority of these studies use academic variables like first year college grades or pre-college attributes such as SAT, math placement scores, high school GPA, etc. as predictors of engineering success (Budny et. al., 1997; Moses et. al., 2011; Middleton et.

al., 2015; Tyson, 2011; Felder, Forrest, Baker-Ward, Dietz, & Mohr, 1993). The conclusions from these studies show that high school GPA, math readiness, and first year college GPA are all fairly accurate in predicting persistence and first year retention for engineering students. In fact, the model by Moses et. al. (2011) focused only on retention of the students at the end of their freshman year, but found calculus readiness as assessed by The Assessment and Learning in Knowledge Spaces (ALEKS) and high school GPA was able to account for almost 80% of the cases looked at. Felder et. al. (1993) took a different approach to see if first year college grades could be predictive of performance in the first engineering course that chemical engineering students take. It was found that this model could only account for 48% of the variance of grade received in the engineering course (Felder et. al., 1993). This demonstrates the range in accuracy for these models which are all trying to find the best predictive variables to be able to make a change or help students that are likely to leave the program.

Other researchers have implemented longitudinal studies to look at the effects of certain variables on longer term retention. A study at Purdue University used student data from a 28-year period where engineering retention was defined as a student still enrolled in engineering as of their 6th semester at the school, found that first semester GPA was the best predictor and most directly correlated to retention (Budny et. al., 1997). Further, the study also points out that high school opportunities and preparation are likely reasons that some students are not initially successful in engineering (Budny et. al., 1997). Another study looked at 8 years of data for science, technology, engineering, and math (STEM) majors and determined that many of the students that leave the field do so after only the first or second course in the major, making the first grade a student receives in one of their major courses a good predictor of retention (Rask, 2010). All these studies show the significance of the impacts that the freshman year courses have on an engineering student for persistence. However, because these studies wait and use terminal predictive measures like grades in their first course or first year college GPA it is challenging to be able to intervene with the students prior to grades being posted. This study also produced a predictive model, but this model is used to support the findings from student experiences in order to provide new recommendations for institutional changes of Calculus I.

These quantitative models have been able to provide universities with statistics that can be used to demonstrate trends and key problem areas on the degree path, but there are also many retention studies that have looked at affective variables for indicators of success in engineering. These affective variables include looking at learning styles, personality traits, attitudes, and emotions. The importance of understanding and activating various student learning styles has become widely discussed in engineering education (Felder & Silverman, 1988). One study looked at student learning styles using Kolb's four learning quadrants and found it correlated with 3-year retention for the 1,000 student cohort studied (Bernold et. al., 2007). Another study at the University of Pittsburgh captured over 400 freshman engineering student attitudes through a pre- and post-survey to correlate with sophomore year retention and allow the college to identify students at-risk of leaving. The findings showed that there were three distinct groups that could be determined through attitudes including those that stayed in engineering, left engineering in poor standing, and left engineering in good standing. Some of the distinguishing attitude differences included an appreciation for engineering as a profession, interest in math and science, confidence to succeed in the major, and influenced by external people to pursue engineering (Besterfield-Sacre, Atman, & Shuman, 1997). This study recommends that determining a student's attitude at the start of their degree program can help schools determine those that are likely to leave and be able to work with these students to persist.

Further, a study by Litzler and Young (2012) using over 10,000 students from 21 schools that completed the Project to Assess Climate in Engineering (PACE) survey approached the issue of attrition by trying to understand a student's level of commitment to engineering by determining if they fall within three categories: 1) Committed, 2) Committed with Ambivalence, and 3) At-Risk of Attrition. There were some interesting findings from this study to support much of the prior literature. First, the At-Risk of Attrition group was small at only 7%, but the authors explain that this is likely due to selection bias of only using enrolled engineering students since "students in their first and second years are more likely to leave engineering than students further along in their education" (Litzler & Young, 2012, p. 337). Further, they mention that the freshman that participated in the survey were much more likely to be the ones in the At-Risk group. Second, the Committed group was correlated to having higher confidence, more student interaction, greater sense of community, and felt valued by professors more (Litzler & Young, 2012). Finally, a study that looked specifically at sense of belonging for STEM students found that it was very impactful for women to feel this sense of belonging while performance measures were more important for men (Lewis et. al., 2017). This highlights the climate of engineering to still be a male dominant field, and to further retain women and minorities it is important to develop a sense of belonging in and outside the classroom. These studies emphasize the insight that can be gained into retention when a researcher considers more affective variables.

There have been two major literature review articles written about retention studies in engineering that further demonstrate the amount of consideration that has been taken to understand this problem. The first was by Peter Daempfle (2002) in which he looked at articles that related to attrition among science, math, and engineering (SME) majors during the 1980s and 1990s to try to synthesis the reasons that students persist or do not persist. The results of the review found that much of the current literature cites the chilly climate of the degree programs, difference in instructor expectations, and high school preparation as the major reasons for attrition from SEM (Daempfle, 2002). Interestingly enough, these same reasons were echoed in the more current 50 study literature review by Geisinger and Raman (2013) that focused on attrition specifically in engineering. These authors found that the major factors that were studied included classroom climate, grades and conceptual understanding, self-efficacy, high school preparation, and interest in the degree (Geisinger & Raman, 2013). These major literature reviews are valuable to stress the common, known factors that cause engineering students to leave, and they both call for a change and the need to further understand how students develop these skills and factors.

2.2 The Effects of the Required Math Courses on Engineering Students

Much of the literature on retention in engineering points out that most students leave the major during their first two years (Budny et. al., 1997; Ohland et. al., 2004; Marra, Bogue, Shen, & Rodgers, 2007; Litzler & Young, 2012). In fact, it has been shown that if a student can get past their freshman courses then they have a very high probability that they will graduate in engineering (Chen, 2013, Budny et. al., 1997). The first two years in most engineering curriculum contains the required math courses, often including Calculus I, Calculus II, Calculus III, Linear Algebra, and Differential Equations, and the required science courses, often including courses in Physics, Chemistry, and Biology depending on the specific engineering major. As a result, many researchers have focused in on these courses to determine how they affect engineering retention. The Calculus series is one particular set that has been shown to have a negative impact on students and it is one of the first required courses these new college students take. In fact, in a nationwide quantitative analysis of STEM majors it was determined that 63% of students that persisted in a STEM major took a calculus or advanced math course during their first year in college, whereas 72% of the students that originally declared a STEM major and left college without a degree took an introductory college level math course or lower during their first year (Chen, 2013). This statistic reveals the impact that the first year, first semester calculus requirement has on retention. If a student that declares engineering as their major is not ready for Calculus I upon entrance, then their likelihood to stay in engineering is greatly reduced.

There have been models created to try to understand the issues with these math courses, which further enforce the importance of math readiness for declared engineering students. A quantitative study showed that both the first math course taken and the grade an engineering student received in that course could be reasonably accurate in predicting engineering student persistence (Middleton et. al., 2015). The exact statistics show a student whose first math course was below Calculus was only half as likely to stay in engineering as a student who took Calculus, and a student that received an A or B in their first math course was 6.5 times more likely to persist compared to receiving a D, F, or W (Middleton et. al., 2015). Another quantitative study found that advanced math readiness as tested on the ALEKS calculus readiness exam and high school GPA are significant predictors of first year math success and engineering student retention (Moses et. al., 2011). The ALEKS exam is often used by engineering programs to determine if a student is ready to enter college calculus based on their math knowledge prior to the start of college. This study provided evidence that this test is a good measure of whether the student will be successful in engineering if their first course is Calculus I (Moses et. al., 2011). Both correlations show how important math readiness is for retention in engineering, and how detrimental a poor initial math performance can be to an engineering student.

While the impact of math readiness is significant, there are other reasons that are cited as to why attrition numbers are so high following the calculus courses which includes the classroom climate of these courses and the lack of connection between the math concepts to the engineering concepts (Venable et. al., 1995; Budny et. al., 1997; Ohland et. al., 2004; Guner, 2013; Middleton et. al., 2015). This has led to another focus of the math persistence literature about implementing solutions to try to solve the commonly mentioned issues. One such change was made at Clemson University to shift Calculus I to a co-requisite with an engineering course rather than a pre-requisite. This was done to allow more students to stay on track with their degree and reduce the pressure to have to take Calculus I their first semester in college. The results show this was beneficial for student retention in engineering, and the change allowed students to enroll in the correct first math course (pre-Calculus) their first semester so then they could be more successful when they took Calculus I. There were also two consequential but valuable outcomes of this change, including a much higher number of students who retook Calculus I if they failed it, and the students had more context for the math concepts they were learning (Ohland et. al., 2004).

Purdue University has recognized this issue for decades now and their engineering program treats the first-year math and science courses as high risk courses that require coordination from all departments involved. This has been shown to be successful for passing and retaining more engineering students, and also shows that calculus is a time dependent course meaning that if the student is not ready for that math level yet then it will reflect in their grade (Budny et. al., 1997). Another program decided to dedicate one day a week of a freshman engineering course to include math concepts to relate the current topics of a student's math course to engineering applications. This was done through organizing the freshman engineering courses based on the level of math each student was enrolled in. The results from the authors perspective is that students did benefit from this combination and had a much better and broader view of how math concepts fit into engineering (Venable et. al., 1995). These larger scale curriculum changes have seen much success in helping engineering students progress through their math courses, but this change has not made a wide scale impact on most engineering programs nationwide.

There has also been interest in determining what the current gap is that has often been discussed between the math and engineering concepts. The purpose to pursue this was made clear in a study done involving senior engineering students that were asked about their experience in the required math courses. The results emphasized that students were desperate for the math content to relate more to engineering and to include more engineering applications in math to be able to relate to engineering concepts. The study also calls for collaboration between engineering and math departments in order to make these changes happen (Guner, 2013). At Massachusetts Institute of Technology (MIT), the Department of Aeronautics and Astronautics worked to create a unified list of math topics to be covered in the math courses and openly discussed these with other engineering and math faculty. This resulted in the realization of the discrepancies between the math instruction and the engineering need for the various concepts leading to the development and dissemination of resources to students and faculty (Wilcox & Bounova, 2004). The value from unifying the concepts from the math courses with engineering students and faculty is likely to be significant for both retention and student learning. Finally, in a study done in the UK the conceptual understanding of both mathematics concepts and mechanics concepts were assessed and it was determined that engineering students do not have a deep understanding of mathematics concepts when compared to mechanics concepts. This is attributed to the type of learning environment of both subjects and the application of them (Munns, 2016). These all point to how disconnected the two subjects are in many engineering programs, and shows both the benefit of what can happen when they are better integrated and the detrimental effects of when they are left as is.

2.3 Student Departure Models

The use of a student departure model as a framework is fundamental to any study about student retention. The final model that was chosen impacts the variables and relationships that were studied. There are numerous models that have already been established and used as a theoretical framework for institutional departure. For this study, the chosen model was adjusted for engineering degree program departure and not necessarily departure from the institution as a whole. Some of the more notable models that were reviewed include The Undergraduate Dropout Process Model by William Spady (1970), The Institutional Departure Model by Vincent Tinto (1975, 1993), The Student Attrition Model by John Bean (1980), The Student-Faculty Informal Contact Model by Ernest Pascarella (1980), and The Student Retention Integrated Model by Alberto Cabrera, Amaury Nora, and Maria Castañeda (1993). This section explains each of these models to help demonstrate why Tinto's model was chosen as the framework for this study.

2.3.1 Spady's Undergraduate Dropout Process Model

Regarded as one of the first retention models, The Undergraduate Dropout Process Model by William Spady was developed in 1970 after he performed an extensive literature search and expanded on the ideas of balance theory, Durkheim's theory of suicide, and current college dropout literature (Spady, 1970). Spady was the first to consider the role that the institution plays on student retention, and found that it was the most powerful predictor for attrition in women (Spady, 1970). Spady based the decision of a student to dropout on that student not meeting both the social and academic system demands, and he tested his model in a longitudinal study at University of Chicago to confirm these pathways (Spady, 1970; Aljohani, 2016). Spady's model is shown in Figure 2.

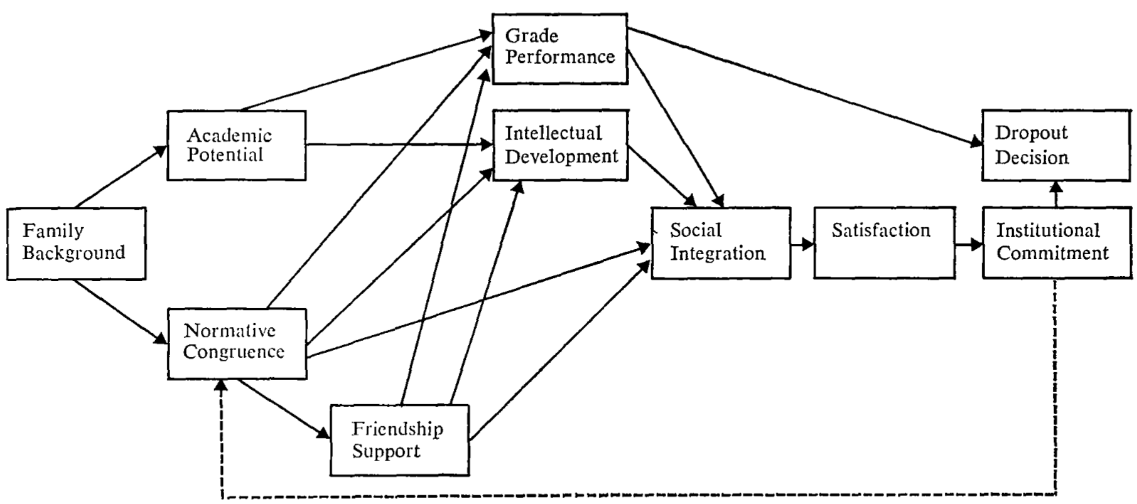

Figure 2. William Spady's Undergraduate Dropout Process Model (Spady, 1970)

Spady's Undergraduate Dropout Process Model was the first to include the responsibility that the institution has in preventing a student from dropping out. This institutional responsibility includes an academic and social system. The academic system includes the grade performance and intellectual development of the student and the social system includes friendship support. Spady's model was limited in the inclusion of factors for each of the two systems and received criticisms on the direct link of grade performance to dropout decision. Spady's Undergraduate Dropout Process Model provided a valuable starting point for other models to be created.

2.3.2 Tinto's Institutional Departure Model

Vincent Tinto's Institutional Departure Model was based on Spady's model and Durkheim's theory of suicide. These two models developed as an analogy to Durkheim's theory for egotistical suicide. Durkheim's description for egotistical suicide was used because it considers the ways that social and intellectual communities influence a society and can lead to voluntary withdrawal from society if a person decides they do not fit in with that community (Tinto, 1993). The analogy was made to education by considering the social and academic community at a higher education institute and if a student does not feel as though they belong then they will depart from the institution.

Tinto published his first model in 1975, but after criticism about the interactions of the academic and social systems and the influence of external commitments to students he added to his original version in 1993 (Tinto, 1975; Tinto, 1993). Tinto's most current model also adopted Van Gennep's *The Rites of Passage* which focused on the stages of separation, transition, and incorporation (Tinto, 1993). These stages were the ones "to move individuals from youthful participation to full adult membership in society (Tinto, 1993, p. 92). Tinto uses these stages as a way to demonstrate a similar process that happens in college and imply that the institution should assist students through these transitions. He specifically mentions the challenges that can arise during a student's first year at college and how important incorporation is during that time for persistence (Tinto, 1993). The influence from all these theories and models helped Tinto create his model for student persistence as shown in Figure 3.

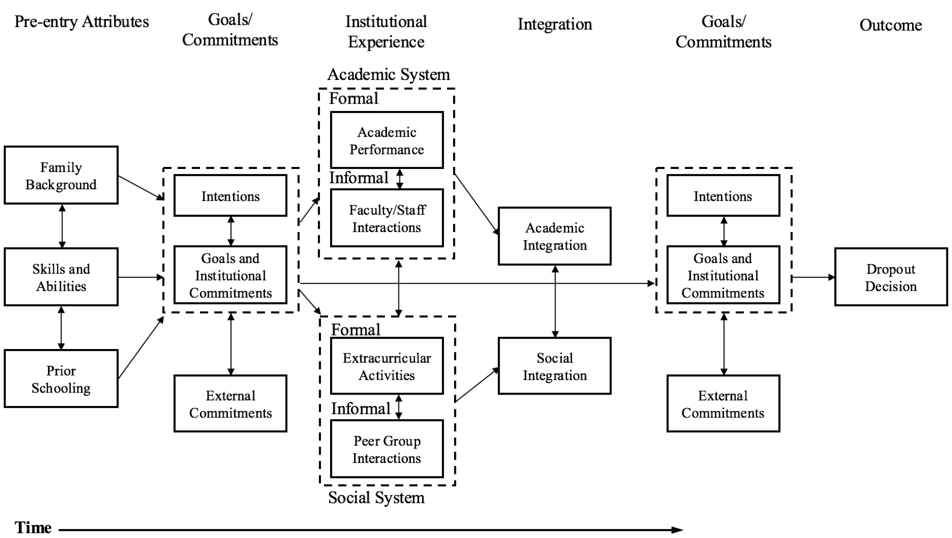

Figure 3. Vincent Tinto's Institutional Departure Model (Tinto, 1993, p. 114)

Tinto’s Institutional Departure Model is a longitudinal model that starts with the attributes that students enter an institution with along with the student’s own goals and commitments. The main focus of the model from the institutional perspective is on the academic and social systems that lead to academic and social integration for the student. Academic integration happens in the formal academic setting through performance or interaction with faculty and staff, while social integration includes the aspects of the student’s everyday life at college. A student needs to integrate in both systems to persist, but depending on the student’s major and institution the needs might not be equal for both systems (Tinto, 1993). Along with integration into both systems, Tinto’s model recognizes the importance of the student's goals and commitments throughout the entire timeline towards making a dropout decision. Tinto's model has been tested extensively in the literature and is the most widely cited student departure framework used (Aljohani, 2016).

2.3.3 Bean's Student Attrition Model

John Bean often criticized Tinto's model and developed his own Student Attrition Model in 1980. His criticisms included a lack of connection between suicide and attrition that the model was based on and that it did not provide a path to explain actual reasons for withdrawal, so Bean looked to an employee turnover model in the work place as a starting point for his model (Bean, 1980). His model took an explanatory approach and considers that students and employees leave for similar reasons. The model consists of four types of variables that affect a student's intentions to stay or leave the institution, which include background, organizational, environmental, and attitude variables (Bean, 1983). Bean developed separate final path models of student attrition for both men women, but the overall summarized schematic is shown in Figure 4.

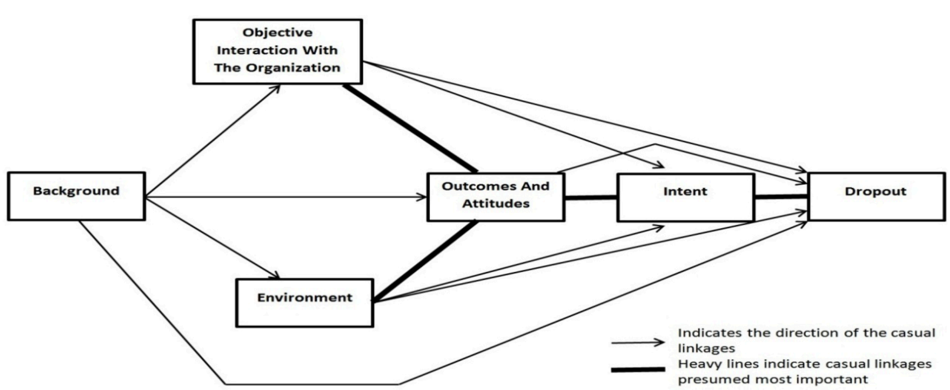

Figure 4. John Bean's Student Attrition Model (Bean, 1982)

Bean's Student Attrition model differs from the previous models through the importance it places on certain factors. His model also includes the background of the students but incorporates the influences of their external environment and the institution which are happening simultaneously and factor into their departure decision. However, the largest influence is the student's intent to stay or not based on their attitude which includes factors that cannot be controlled by the institution. This model is not specified for a certain type of student population, so Bean's model has been adjusted and used for many different student groups including non-traditional students.

2.3.4 Pascarella's Student-Faculty Informal Contact Model

Ernest Pascarella worked closely with Patrick Terenzini using Tinto's model as a guide to study student faculty informal contact both in and outside of the classroom and found that it was significantly related to freshman year persistence (Pascarella, 1980). This led to the development of his conceptual model that still includes similar variables as Spady and Tinto's model like background characteristics and institutional factors, but the major focus is on the student-faculty contact that can influence student persistence. Pascarella states that colleges can impact their students significantly through the "extent and quality of student-faculty informal contact" (Pascarella, 1980, p. 565). Pascarella's model is shown in Figure 5.

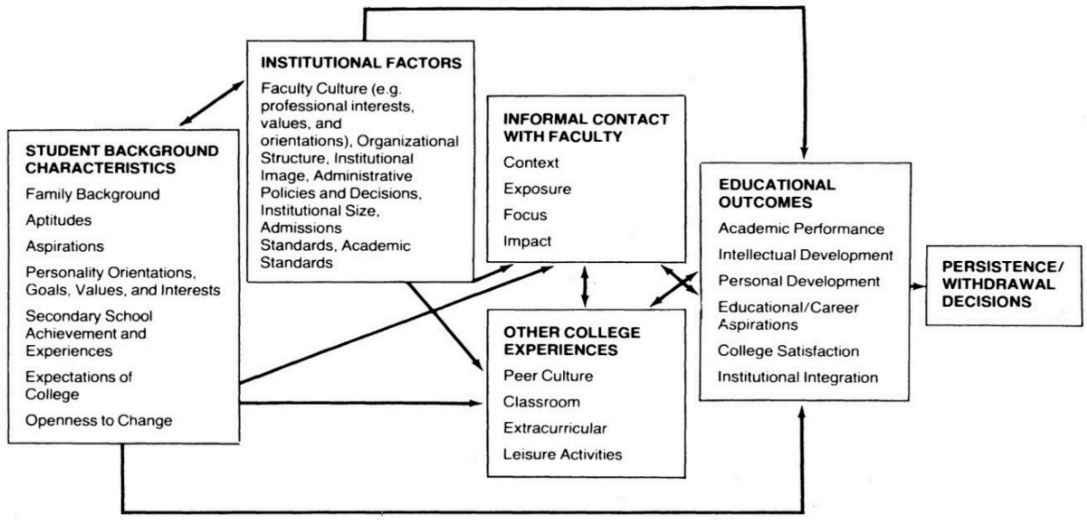

Figure 5. Ernest Pascarella's Student-Faculty Informal Contact Model (Pascarella, 1980, p. 569)

Pascarella’s Student-Faculty Informal Contact Model is also a longitudinal model that begins with the student’s background and the culture of the institution. The model highlights both the informal contact with the faculty and other informal interactions with peers and activities. The importance of the informal contact with faculty was found to be significant to Pascarella and is a major factor of difference for this model compared to the others. Finally, the model includes the academic and social outcomes that a student experiences at an institution and how that factors into their decision to stay or leave.

2.3.5 Cabrera, Nora, and Castañeda’s Student Integration Model

The final model that is relevant to retention studies today is the Student Retention Integrated Model created by Alberto Cabrera, Amaury Nora, and Maria Castañeda (1993). These researchers found significant overlap between Tinto’s Institutional Departure Model and Bean’s Student Attrition Model and decided to develop an integrated model. The integrated model incorporates the commonalities between the two established models including pre-college attributes, academic integration, and institutional factors, but the new model also includes the differences between the two like the role of external factors on the student from the Student Attrition Model and grades as indicators of academic integration from the Institutional Departure Model (Cabrera, Nora, & Castañeda, 1993). The authors have argued that their model is the most robust and can validate the most hypotheses through its use (Cabrera, Nora, & Castañeda, 1993). The final model including the significance of each path is shown in Figure 6.

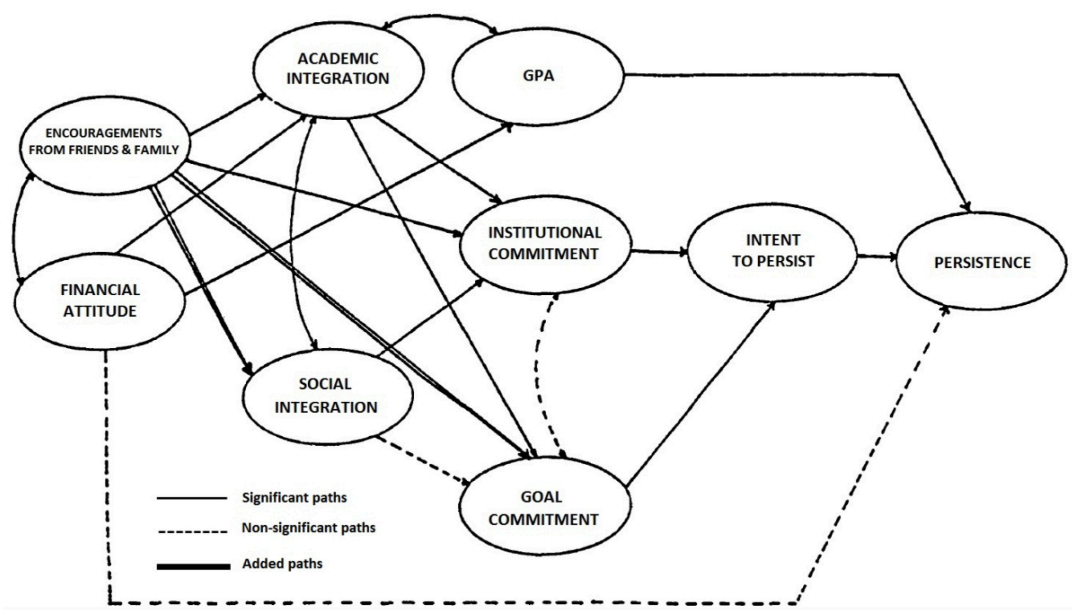

Figure 6. Cabrera, Nora, and Castañeda's Student Integration Model (Cabrera, Nora, & Castañeda, 1993)

Cabrera, Nora and Castañeda's Student Integration Model shows a more complex integration of all the factors that can lead to persistence. This model is different in that it places both encouragement from family and friends and financial attitude as separate constructs and the initial factors that should be considered for student retention. The next factors are similar to Tinto's and focus on academic and social integration that have some relationship to each other along with all the variables that follow. This model also includes a student's goal commitment which leads to their intent to persist as highlighted in Bean's model. This intent along with GPA, which was important to Tinto's model, factor into the final decision to drop out or persist. This Student Integration Model may be the most robust model for student departure because it includes the most pathways, but it is not as clear on which factors are most significant for persistence.

2.3.6 Comparison of student retention models

The models described in this section include the most common models that have been developed and used to try to understand attrition from a university. These models were developed for traditional 4-year institutions that have a traditional student population who typically enter and reside at the university right after high school (Aljohani, 2016). There have been adaptations to some of these models made to study different populations including commuter schools, non-traditional students, and community colleges (Bean & Metzner, 1985; Nora, 1987; Bean & Eaton, 2000; Bers & Smith, 1991). There have also been other developments of newer retention models that have not yet been studied and validated as much as the five discussed here (Weng, Cheong, & Cheong, 2010). The variety of student retention models covers a wide range of issues in higher education, so it is the researcher's choice of model that impacts the importance placed on the variables and type of data that will be studied. After comparing the strengths and weaknesses of the models, Tinto's Institutional Departure Model was chosen as the best fit for the present study. The reasons Tinto's model was chosen over the other models that were reviewed include:

- The model is based in sociology instead of psychology. This is important to this study because a sociological model focuses on the society at the institution and how that affects student persistence. Conversely, a psychologically based model focuses on the individual student and how that individual student interacts with the university environment. To approach this problem from institutional change the focus needs to be on the whole student population and how institutional changes can affect that society.
- The institution plays a major role in developing student persistence. The importance of the institution is included in the formal and informal academic and social systems in Tinto's Institutional Departure Model. These four systems can be studied and understood leading to the creation of modifications that can be made to each which will provide a better integrative experience for the student into the institution and engineering degree program.
- The use of the social and academic community indicates the importance of having students develop a sense of belonging. A sense of belonging is extremely important for engineering students to develop early on and to do so in both the classroom and outside of the classroom. There are many challenges for engineering students to create a community with other engineering students, faculty, and staff early on due to a lack of engineering courses and activities offered during their first year, so considering the

development of their sense of belonging early on is important for understanding their decision to persist.

- Academic performance is considered a major contributor to academic integration. Many of the other models do not consider academic performance as one of the major factors contributing to persistence. For engineering students, this is a significant factor because these students must receive certain grades in certain prerequisite courses in order to continue on in engineering and maintain a specified overall GPA to be able to apply for the engineering professional program. The importance of academic performance for engineering students is more significant than other majors and plays a major role in their persistence.

Some of the uses of Tinto's model to study retention will be discussed in the next section.

2.4 Use of Tinto's Institutional Departure Model

Tinto's model has been used extensively and often been expanded on in the literature (Pascarella & Terenzini, 1983; Berger & Milem, 1999; Karp et. al., 2008; Weng, Cheong & Cheong, 2010; Nevill & Rhodes, 2004; Severiens & Schmidt, 2009; Hoffman, 2003). There is no shortage of research studies that include the Institutional Departure Model as the framework used, but this section will introduce only a small portion of studies found to be most relevant to the current research project.

In a case study by Borglum and Kubala (2000) on community college students, a survey was used to determine the academic and social climate of the college and correlate this with background variables and persistence in college. The research questions and survey questions focused on determining how academic integration and social integration led to retention and how the academic skills differed between those that were retained and those that left. The results indicated that often students who felt academic integration also felt social integration, so these seemed to be connected at this college, but they could not correlate the two with attrition. This result is attributed to the student population used since it was primarily students in their second semester, but the background variables did prove to be significant on retention (Borglum & Kubala, 2000). This implies that all variables from Tinto's model should be considered when trying to understand persistence, and for some majors there is a clear link between academic and social integration. Another study that focused on engineering persistence by Tyson (2011) adapts Tinto's model to include the specific variables relevant to engineering students. This includes high school math and science grades for the pre-college characteristics, college math and science grades for academic integration, and community college enrollment for social integration. The results did not show a significant correlation between students who had high academic integration (A's in their college courses) compared to those that did not on whether they left the engineering major. There was also not a significant correlation found for social integration (Tyson, 2011). These results imply that there is more going on than grades that leads to students leaving engineering. Finally, a study by Hoffman (2003) developed an instrument to try to understand a student's sense of belonging during their first year in college and to understand student persistence based on Tinto's framework. The created Sense of Belonging instrument was a survey that included items to assess a student's perceived peer support, perceived faculty support, perceived classroom comfort, perceived isolation, and empathetic faculty understanding, and it will be used in future studies to determine how these relate to persistence (Hoffman, 2003). This has been an important addition to attrition research because the idea of sense of belonging, which "is theorized to reflect students' integration into the college system" (Hoffman, 2003, p. 228), has not often been included in departure research due to a lack of conceptual guidance. This instrument provides a draft protocol for how to investigate these deeper student attachments when evaluating integration. These studies have been influential on the scope of this research project and on informing the style of research method used.

2.5 Mixed Methods Research for Engineering Persistence

The three studies above suggest the value of having both quantitative measures to evaluate academic integration and qualitative measures to try to understand the students' sense of belonging in the academic and social system. This led to the use of a mixed methods research design for this project that will include both quantitative and qualitative data collection and analysis to understand integration in both the social and academic system. The use of mixed methods research is a newer research approach, but has been increasing in use in the field of engineering education (Borrego, Douglas, & Amelink, 2009). The article by Borrego, Douglas and Amelink (2009) provides the different design types that have typically been used and gives examples of each type of mixed method study done recently in engineering education to highlight the value of this research method. This section reviews three notable examples of mixed method research pertinent to engineering persistence done in recent years.

A mixed method study by Suresh (2007) combined both survey data and interviews to validate a persistence model for engineers. The study follows an explanatory design using the quantitative survey data to inform the qualitative data, but the results emphasize the quantitative results. The survey was completed by 590 junior and senior engineering students who answered questions on a 5-point Likert scale about their high school experience, study and attendance behaviors, faculty behavior, and engineering culture of support. It was found that all these factors were significantly correlated to grades in barrier courses. Then fifteen interviews were done with students to try to gain further insight into their freshman and sophomore year experience. This study highlighted the issue with the freshman math and science courses known to be barrier courses and found that performance in these barrier courses and motivation to be an engineer were significantly correlated to persistence in engineering. The interviews further complimented this by showing that barrier course performance often led students who persisted to question their path in engineering (Suresh, 2007). This study furthers the argument to understand the academic and social environment of each of these barrier courses and how it can help students integrate into the degree culture. The implementation of this study was meaningful to show how the persisting students valued the survey items, but the population was limited to only persisting engineering students since only junior and seniors were asked, which needs to be remembered when reviewing the data.

Another study by Amelink and Meszaros (2011) used a concurrent mixed method design but emphasized the quantitative data again in the results to determine the difference in male and female motivations to persist in engineering. There were surveys disbursed to nine institutions that included 114 questions about career choice, self-assessment abilities, classroom experience, support network, engagement, department climate, and background. Then focus groups were completed at each campus using a semi-structured interview to share their experience with the faculty, department, and career goals all relative to getting an engineering degree. The results were analyzed to look at differences in gender and persistence, and it was found that job opportunities were one of the defining differences where females were less likely to see job opportunities and salary potential in engineering after 10 years in the field than males. Another major factor was found in the classroom, where peer competition and grades affected female self-determination more than males causing them to be more likely to leave engineering earlier than their male cohorts. The interviews uncovered these major intrinsic factors that were unique to each student (Amelink & Meszaros, 2011). This study highlights the importance of understanding individual student perspectives and how that can factor into retention, and it emphasizes the difference in the needs of a learning environment for different types of engineering students.

A final example of a mixed method study by Meyer (2015) used a concurrent design that emphasized the qualitative results to describe why students left an engineering degree program. The study compared several demographic factors between persisting and non-persisting engineering students to determine a profile for the two different groups. Then the research took an in depth look at the stories of students that left engineering through an interview and journey map. The results indicated that there are certain demographic factors such as age, high school GPA, marital status, and other variables that could be significantly correlated with engineering persistence, but the new findings came from the qualitative analysis. These results showed there was often emotional factors that contribute to students leaving engineering, where some of the biggest factors included not feeling prepared for the coursework, not fitting in, and other institutional factors (Meyer, 2015). This further enriches the idea that there is much to be learned about engineering persistence from the actual individuals that is not captured by quantitative data.

2.6 Summary of Literature Review and Significance of Current Study

This literature review has provided information on the importance of engineering student retention and how the math courses can significantly affect persistence (Fortenberry et. al., 2007; Ohland et. al., 2004; Litzler & Young, 2012). It also provides a summary of the major attrition models that are currently being used to try to study this problem in all of higher education, which demonstrates the range of variables that are thought to factor into a student's decision to stay or leave. These models represent a variety of perspectives that can be used when approaching this problem. However, after careful consideration of all the applications and focus of each model, the model chosen for the framework of this project was Tinto's Institutional Departure Model (Tinto, 1993). This model was chosen for its focus on requiring both social and academic integration into an institution, which has been shown to be a challenge for engineering students to develop these in the early math courses.

The review then discusses how Tinto's model has been used in practice to inform the type of data and type of questions that have been asked in attrition projects. Many of the studies approach integration through quantitative data collection since it is easier to analyze for a larger population, but there is significant value found in using qualitative data and gathering the student perspective about the issue of persistence. The benefit of qualitative data collection and analysis is reiterated in the mixed method analysis review, further convincing the researcher to use a mixed method research design for the current project.

All of these studies have either shown the scale and importance of the problem of engineering student retention, especially after their freshman year, or a route to understanding the problem. However, there is still much to be known about the actual environment and activities specifically in Calculus I and how that course directly affects engineering persistence. There are still many institutions that offer that math course through a separate math department causing the disconnect from engineering which has been shown to be one of the major reasons for the significant freshman year engineering retention problem. This gap creates the need for a deeper understanding of the student perspective about Calculus I and how that course can help students develop academic and social integration into engineering. In addition, there is a need for an update on the statistics that show how Calculus I affects retention. The combination of these two analyses will compliment and add to the existing literature to offer engineering programs a better understanding of ways they can help students during this challenging time.

CHAPTER 3

METHODOLOGY

This research study used a mixed methods approach following a *partially mixed sequential dominant status design* (Johnson & Onwuegbuzie, 2004; Leech & Onwuegbuzie, 2009). The name *partially mixed sequential dominant status design* describes the three important dimensions of the mixed methods design that will be used: (1) partial- the level of mixing for this study, (2) sequential- the time component of when the quantitative and qualitative approaches will take place, and (3) dominant- one of the approaches will be emphasized more than the other (Leech & Onwuegbuzie, 2009). This research study took a quan→QUAL approach which implies that the quantitative (quan) data collection and analysis happened first followed by the qualitative (QUAL) data collection and analysis. The results emphasized the qualitative analysis (as symbolized by the capital letters). The partial mixing happens in two places as indicated by the dashed arrow and dashed box on Figure 7. The first instance of mixing is the use of the results from the quantitative analysis to inform the interview questions for the qualitative analysis. The second mixing takes place at the end through a synthesis of all the results to answer the third and final research question. The quantitative portion of the study is important for understanding the big picture of the persistence problem at the university of interest and the impacts that the various academic variables can have on a student, but the qualitative portion is more heavily weighted because it will provide a deeper and richer understanding of the issue which cannot be assessed through quantitative analysis. The overall flow of the research study is shown in Figure 7.

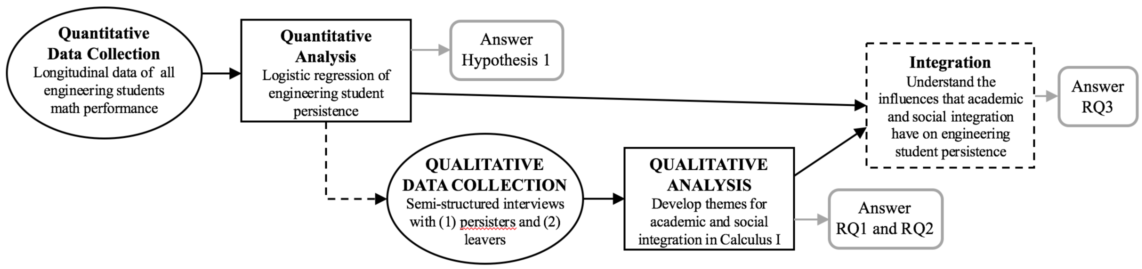

Figure 7. Mixed method partially mixed dominant sequential design

Pragmatism is the philosophical basis for this study. Pragmatism was developed by the early philosophers: Charles Sanders Pierce, William James, and John Dewey, as a middle ground between the dualistic philosophies and methodologies of the traditional philosophers and researchers (Johnson & Onwuegbuzie, 2004; Morgan, 2007). At the core of pragmatism is the intent to use research as a means to impact practice or take action (Johnson & Onwuegbuzie, 2004; Morgan, 2007). Pragmatism is often referred to as the middle ground between philosophies and methods because it considers both induction and deduction in the analysis, subjectivity and objectivity to the research process, and has a goal of transferability of the results (Morgan, 2007). These qualities provide a meaningful philosophy for this research project to try to understand this problem in engineering education and inform change to the curriculum based on the results. The pragmatic approach aligns with the use of a mixed methods research design because it allows the flexibility to investigate the issue from various positions along with reporting the important implications of the research (Morgan, 2007). It also supports the use of creating a study based on the intended purposes of it, the available resources, and to do what makes sense (Patton, 2002). As a result, in this research project the use of different sources of information are determined to be key to uncovering the answers (Mason, 2002; Creswell, 2013). While there may not be an absolute truth that will result from this project, it will provide a justification for action while offering evidence to support that action. This pragmatic perspective has played a significant role in guiding the study, shaping the research questions and hypothesis, and the interpretations of the results (Denzin & Lincoln, 2006).

For this study, the best available data sources included longitudinal data of student performance in their math courses and interviews with students about their experience in Calculus I at the institution where this study took place. These data sources were analyzed separately and together to determine the broad impact of the problem and the current institutional influences that are causing it. The quantitative analysis resulted in a statistical model that shows the importance that Calculus I performance has on engineering student persistence. The qualitative analysis used student interviews to determine themes to uncover how the Calculus I course impacts integration into the engineering degree program. The qualitative analysis will uncover common themes for integration amongst two groups of students: persisters and leavers.

3.1 Theoretical Framework

The entire study was grounded on the theoretical framework of Vincent Tinto's Institutional Departure Model (Tinto, 1993). As described in Chapter 2, there are many models for institutional departure that have been created. Vincent Tinto's (1975, 1993) model has been chosen as the most fitting for the purpose of this study because it's a sociological model that focuses on the role of the institution in student persistence, the development of a student's sense of belonging socially and academically into the institution, and highlights the effect of academic performance on student persistence.

Vincent Tinto's Institutional Departure Model is a longitudinal model that describes persistence as an interaction of many factors. He acknowledges that students come into college with pre-entry attributes and goals that will affect their persistence especially in the beginning. However, his model focuses on the influence of two systems that play the major role in student persistence: the academic system and social system. If a student is not able to integrate into both, they are likely to depart from the institution (Tinto, 1993). The academic system is focused on the classroom, faculty, and education of the student while the social system centers on the personal aspects of the student in their daily life. Tinto states that the impact from the two systems is varying and often interwoven and dependent on the degree program and institution, but the minimum standard must be met for both to have success (Tinto, 1993). Tinto's model is shown in Figure 8.

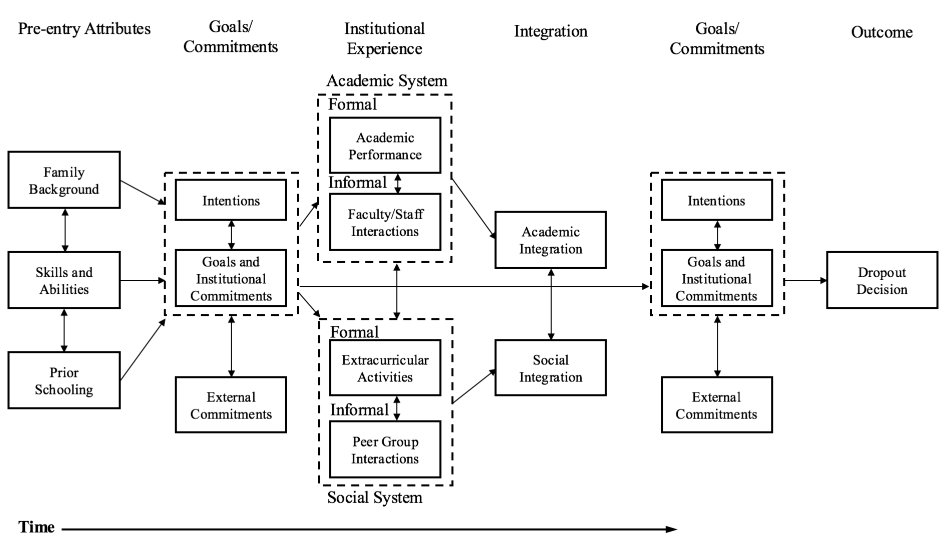

Figure 8. Tinto's Institutional Departure Model (Tinto, 1993, p. 114)

This research study focused on understanding the academic and social integration that an engineering student experienced during their Calculus I course and how that influenced their persistence in the degree. *Academic integration* is defined as a measure of a person's ability in their academic endeavors including academic performance and ease of interaction with faculty and stuff about topics relative to the student's degree. *Social integration* is defined as a measure of a person's ability to be involved and interact with the community outside of their formal academic environment including interaction with peers, other engineering students, and involvement in extracurricular activities at the institution.

The social system for students of any major is an extremely important aspect to consider for retention. If a student feels like they are a part of the community, then this can encourage them to persist even if their academic performance has suffered. This was shown in Alexander Astin's (1993) book *What Matters in College: Four Critical Years Revisited* where it was found through a study of almost 25,000 students that one of the most prevalent influences on a student's development was their peer groups. He states that "the student's peer group is the single most potent source of influence on growth and development during the undergraduate years" (Astin, 1993; Feldman, 1994). This implies that it does not matter the student's major, but they will be heavily influenced by their social circle which is why it is a major focus in Tinto's model. However, for engineering students the academic system is also a significant factor to consider for persistence. An engineering degree program is known for its academic rigor, and it is important to consider how academic performance factors into the student's decision to stay.

Engineering students are expected to pass and progress through the Calculus series during their first two years of college, which Tinto (1993) has noted are especially formidable years, and if they are not successful in these prerequisite classes they are likely to leave the degree (Budny et. al., 1997; Ohland et. al., 2004; Middleton et. al., 2015). The unfortunate issue with students leaving the degree program this early on is that it is prior to taking an actual, theory-based engineering course. The GPA requirements for engineering students are also extremely high, and many students who are transitioning into higher education struggle to meet these expectations at first. As a result, they choose to switch to a different major that they believe they will be more successful in.

These two major systems play an important role for engineering students which is the reason Tinto's Institutional Departure Model was chosen as the theoretical framework; however, the departure in this study will be from the engineering program and not necessarily the institution. Additionally, this model is the most appropriate for this study because it is based in sociology. The sociological implications of the results are ones that can influence action and implement changes on a large scale to help these engineering students, so it is important to uncover what these are. Tinto's model also considers academic performance as a contribution to academic integration and not just an outcome. In engineering, a student's academic performance is important for staying on track in the degree path, and every course is significant in impacting a student's commitment. Further, as freshman students, new to college, the social system that a student finds can be very impactful on them, but in these Calculus courses it is possible that a student is not able to find or get involved with a group that is supportive of their chosen degree, which will influence the student's path. As a result, the focus of this study was on Calculus I which is often the first required course in an engineering student's degree path to uncover the academic and social systems that these students encounter and how they contribute to developing both academic and social integration in the engineering program.

3.2 Research Positionality

As the single researcher in this study, it is important to be reflexive of my position. Reflexivity requires having constant awareness of myself relative to the research work and the perspective I am bringing to all aspects of the project (Blair, 2015). As an engineering education researcher, I am driven by the desire to be able to apply all research to practice. I have experienced and seen the issues with these Calculus courses first hand and feel that there are changes that can be made to minimize the number of students that are not successful in these courses. I have spent time as both an engineering student that has had to take Calculus courses offered through a mathematics department and as a faculty member for sophomore civil engineering courses that had these math courses as direct pre-requisites. These positions have influenced my selection of Tinto's Institutional Departure Model as the theoretical framework for the study because I have seen the impacts of academic and social integration on engineering students. It was during my time as an instructor that I realized the lack of connection the math courses had to most engineering courses, or in reality, the lack of connections the students were able to bring from their math courses to their engineering courses. After doing a literature review, it was clear that this was a well cited issue and there have been many routes taken to try to understand this problem. This led me to use a mixed method path of inquiry to be able to provide the richness of results that I could use to support the need for change. I have personally witnessed this issue at two major engineering colleges in the U.S., and as a result, can see the potential from understanding and intervening in the math courses for engineering students in the future. These experiences have shaped the purpose of my research to be an opportunity to understand the issues of Calculus I at the student level with the hope to spark conversations about curriculum redesign.

3.3 The University

The university that the student data was collected from is an R2: Doctoral University in the Rocky Mountain region with accreditation from ABET for all engineering bachelor degree programs. At the time of the study, there were seven undergraduate degrees offered: biological, civil, computer, electrical, environmental, and mechanical engineering and computer science. The College of Engineering currently has approximately 2,600 undergraduate students enrolled out of 16,000 total undergraduate students at the main university campus where the College of Engineering resides. All engineering students must work their way through the pre-professional program during their freshman and sophomore year at the university. It is during these years the students must complete all their required math courses in order to pass to the professional engineering program during their junior and senior years. A student's entrance into the professional program is dependent on the student's academic performance where the following must be met:

- must have a C- or better in every required engineering, math, and science course

- cannot have more than three repeats in the engineering, math, and science courses
- GPA requirement of:
    - 2.3 (on a 4.0 scale) or higher for Civil, Environmental, and Biological majors
    - 2.8 (on a 4.0 scale) or higher for Computer, Electrical, and Mechanical majors
    - 2.5 (on a 4.0 scale) or higher for Computer Science majors

All seven of the undergraduate degree programs require a student to take Calculus I during their first semester at the university to stay on track and graduate within four years. Calculus I and Calculus II are required for all seven degree programs, while Calculus III is only required for civil, electrical and mechanical engineering students. If a student is not ready to start in Calculus I during their first semester at the university then it is likely they will be off track in their program resulting in the need to take courses during off-semesters, take summer courses, or delay their graduation. In order for a student to be able to take Calculus I upon entering college they must have met one of the following requirements: Math ACT score of 27 or higher, Math SAT score of 620 or higher, completed college level algebra and trigonometry with a grade of C-, AP Calculus AB score of 3 or higher, or a high enough score on the Math Placement Exam given by the university. If a declared engineering major does not meet one of those requirements then they must start in a lower level math course, throwing them off the typical engineering 4-year plan.

At the university, Calculus I is offered through the math department and taught by a constant rotation of instructors due to changes in teaching assignments, faculty preference, and faculty hiring. For any one semester there may be up to 6 different instructors assigned to the different sections, but the students do not know who their instructor will be until the course begins. Within the last 4 years, the math department has created some Calculus I sections that have two lectures a week and two recitations a week, but prior to that the sections were all offered as 4-day a week lecture courses with 100-300 students registered in each section. Students also have the option to take a broadcast section of the course or an online section, but there is only one offering of these sections a semester. Due to the vast number of instructors and wide variety of teaching methods that have been used for Calculus I over the 13-year period of this study, the authors did not factor in these differences because the populations were very small for some sections.

3.4 Quantitative Strand

The use of the quantitative research portion of this study was to be able to generalize the results based on the population and to validate the claims that have already been made in the literature (Johnson & Onwuegbuzie, 2004). It has been shown that these math courses are potential stopping points in an engineering students' path, but the literature lacks the statistical significance of this especially on a student level (Budny et. al., 1997; Ohland et. al., 2004; Guner, 2014; Middleton et. al., 2015). The quantitative analysis used both descriptive and inferential statistics to answer the hypothesis.

All student data was extracted from the Banner system at the university through partnership with the Registrar's Office and IRB approval. Banner is a large software application created by Ellucian that contains a large database of student records including transcripts and all other relevant data. The data was pulled by the Registrar's Office and provided to the researcher with unidentifiable ID numbers created for each student to ensure anonymity while completing the analyses. The program SAS System ® was used to execute all the statistical procedures used in this research. SAS is a very robust statistical analysis system that enables predictive analytics.

3.4.1 Hypothesis

This portion of the study used statistical analysis to prove or disprove the following hypothesis that is relevant to academic integration in engineering:

1. The academic integration of an engineering student as measured by academic performance in Calculus I is correlated with their persistence in the engineering degree program.

Rationale: A student is likely to depart if academic integration does not happen as a result of a mismatch of the student's skills or abilities with the requirements of the academic system (Tinto, 1993). Further, for engineering students, it has been shown that math readiness and performance can be predictive of their persistence (Middleton et. al., 2015).

3.4.2 The Population

The population that was selected for this part of the study consisted of all declared engineering students that took Calculus I at a major research university in the Rocky Mountain region between fall 2005 and spring 2018. There were 3,927 students contained within the 13 years of interest that were enrolled in Calculus I at least one time at the research university as a declared engineering major. After taking Calculus I some of the students may have switched majors out of the College of Engineering or left the university all together marking them as leavers in the analysis. The data does not consider any engineering student that may have come to the university with their Calculus I requirement already fulfilled either through Advanced Placement (AP) credit or transfer credit from another university. There were two groups of interest used for each analysis procedure. The first group of students contains all students in the population. Within the all student group, these are split into two groups: (1) persisters, the students that are still registered or have graduated as engineering majors, and (2) leavers, all other students in the 13-year data set. The second group was the graduated student group which contains only students, initially declared as engineering majors, that graduated from the university. Within the group of graduates there are: (1) persisters, the students that graduated with an engineering degree, and (2) leavers, the students that graduated from the university with a degree other than engineering. The breakdown of the population used within this study is given in Table 1.

Table 1

Student demographic breakdown

	Total	**All Persisters (% of total)**	**All Leavers (% of total)**	**Graduated Persisters (% of total)**	**Graduated Leavers (% of total)**
Male	3432 (87%)	1777 (89%)	1655 (86%)	803 (90%)	395 (81%)
Female	495 (13%)	229 (11%)	266 (14%)	85 (10%)	90 (19%)
Total Students (Male + Female)	**3927**	**2006**	**1921**	**888**	**485**
Retaker*	605 (15%)	267 (13%)	338 (18%)	121 (14%)	88 (18%)

*Retaker is not part of the summation for total students

However, due to missing data for certain independent variables, the number of participants used in each analysis may differ than the total number given above. The sample size used for each statistical procedure is given with each result.

3.4.3 Statistical Analysis Methods

The dependent variable of the analysis was persistence in engineering. This was determined from the given data as students that are still registered at the university in an engineering degree program or graduated from the university with an engineering degree. The students that were part of the group of leavers are students that graduated with a degree other than engineering, are still registered at the university but in a college other than engineering, or are reported as absent, suspended, or inactive. For the model persistence was coded as a dichotomous variable, either 1 or 0, based on the student's status as a persister or leaver. The Calculus I grade that a student received in the course was used as an independent variable but classified as a continuous variable. This was done based on the use of the plus/minus grade system at the research university, so to minimize the degrees of freedom used for that variable it was considered continuous. This variable and the remaining independent variables that were considered in this study are described in Table 2.

Table 2

List of Independent Variables

Independent Variable	Variable Type	Variable Range	Reason for Inclusion
Calculus I Grade	Continuous variable	Values range from 0.0-4.0, including +/- grades	Determined to be an indicator of persistence in engineering
Retaker	Categorical variable	Coded as 1 or 0 (1=student has taken Calculus I more than one time)	Determined to be an indicator of persistence in engineering
Gender	Categorical variable	Coded as 1 or 0 (1=female)	Common variable in literature
Admission Index	Continuous variable	71-142 (computed using ACT Score, HS GPA, and other admission factors)	Common variable in literature
HS GPA	Continuous variable	1.4-4.0	Common variable in literature
ACT Score	Continuous variable	11-35	Common variable in literature
ACT Math Score	Continuous variable	14-36	Common variable in literature

The focus of the statistical analysis was to understand the impacts of grades received and to create a logistic regression model for the two groups of students (graduated and all students). A logistic regression analysis was the most appropriate model because the dependent variable is dichotomous. It also has advantages over other statistical techniques because it can be interpreted using odds ratios given in terms of probability (Mau, 2003). The independent variables were selected in a stepwise procedure based on significance, with α set at 0.05, where the most significant factors were brought into the model by stepwise selection until there was no significant change in the model due to adding additional variables. The statistically significant change in the χ^2 for each additional variable was measured to determine the fit of the model. The results also included parameter estimates for each variable to build the predictive model. In addition, a correlation analysis for several of the variables was run to determine if there were any confounding variable issues in the model. There was also pilot data analyzed from the same data set that was used to inform the interview questions for the qualitative portion of the research project.

3.4.4 Pilot Data Analysis

Prior to cleaning up the data to include only Calculus I data for the final statistical analysis there was other data analysis performed to understand the student population. This analysis looked at each student's math trends including their grade trends in their math courses, looking at the grade trends for students that had to retake Calculus I, and looking at the typical math sequence that the students took. This section will only include the relevant results to this study as they influenced the interview questions used in the qualitative strand of this project.

It was found that the typical math sequence that the declared engineering students would take was extremely variable and ranged from taking a single course, Calculus I, at the university to a series of six different math courses depending on prerequisite needs and major requirements. As previously stated, all engineering students are required to take Calculus I upon entrance to the university in order to stay on track. However, there was a large number of students that still took one or more math courses prior to Calculus I. These courses could include trigonometry, pre-calculus, or any math course offered that is prerequisite to Calculus I. It was also previously stated that Calculus I is typically a barrier course that causes students to leave the major just after taking it (Ohland et. al., 2004; Daempfle, 2002; Rask, 2010). The data showed that there was a large majority of students that continued on to at least one more math course following Calculus I, which could include Calculus II, linear algebra, or differential equations. The following table reports the number of students that took a math course before and/or after Calculus I.

Table 3

Number of students that took a math course pre/post Calculus I

	Number of Students (% of total)
Students that took a math course before Calculus I	1830 (47%)
Students that took a math course after Calculus I	2651 (68%)
Students that took a math course both before and after Calculus I*	1111 (28%)
Total students	**3927**

*These students are included in the counts found in row 2 and 3 of the table also

The large number of students that took a course prior to Calculus I or after Calculus I led to the development of questions about Calculus I preparation. These questions were included in the interview as part of the experience questions. All the interview questions can be found in the appendix.

3.5 Qualitative Strand

The purpose of the qualitative analysis in this research project was to better understand the environment of Calculus I from the students themselves. The qualitative portion of the project was given a heavier weight in the results section since the value of the student perspective will be significant in understanding and unravelling the issues in Calculus I for engineering students, and will "produce explanations" for the problem of the study (Mason, 2002, p. 7). The constructs of academic and social integration are personal experiences that can only fully be uncovered through understanding each person. One of the primary characteristics of qualitative research was to focus on the participants' meanings and learning about the issue from that perspective and not just the literature (Creswell, 2013, p. 47). Another strength of qualitative analysis was to provide explanation and reason to a problem that is common among engineering programs, but cannot be deeply explained by quantitative trends (Kelly & Bowe, 2011).

The research project explored 10 student accounts of their Calculus I course about a year after they had taken it. The target population included the students who took Calculus I about a year prior because they could reflect more objectively on their experience in Calculus I due to time passing (Meyer, 2015). They also have experienced at least two semesters of courses after taking Calculus I and could make connections to how Calculus I impacted their following courses. There were two types of students that were recruited, those that have remained in engineering since Calculus I and those that have left engineering since taking the course as an engineering student. All participants were recruited with the help of the Registrar's Office and staff in the Department of Engineering Education following the approval from the Institutional Review Board (IRB).

3.5.1 Research Questions

There are three qualitative research questions focused on understanding and describing the experiences an engineering student had during their Calculus I course. The first two questions try to understand the development of social and academic integration as a result of this course. The third question will compare the experiences of persisters and leavers in engineering and determine if there was a difference between the groups.

1. How does an engineering student's academic integration develop during Calculus I?

2. How does an engineering student's social integration develop during Calculus I?
3. In what ways does social and academic integration differ for engineering persisters and leavers?

3.5.2 Participants

The participants for the qualitative study were selected using purposeful maximal sampling to consist of two different groups (Merriam, 1998; Patton, 2002; Yin, 2003; Creswell, 2012). This sampling technique allowed the student participants to be selected that could provide different perspectives to the research problem, in this case, the research is interested in two different perspectives (Patton, 2002; Creswell, 2012). The first group is considered the persisters who have stayed in an engineering degree program since taking Calculus I. The second group is called the leavers and they have switched out of engineering since taking Calculus I. All participants in both groups had to have taken Calculus I during the spring or fall 2017 as a registered engineering student in the pre-professional program. This classifies a persister as a student who has remained in engineering for 1.5-2 additional years after Calculus I. There were six persisters and four leavers that were recruited for the study. These numbers are broken down in Table 4.

Table 4

Interview Participants

	Persister	**Leaver**
Male	4	1
Female	2	3
Took Calculus I 1st year, 1st semester	2	1
Took Calculus I 1st year, 2nd semester	3	0
Took Calculus I 2nd year, 1st semester	1	2
Took Calculus I 2nd year, 2nd semester	0	1
Total	**6**	**4**

The participants were recruited with the help of the Registrar's Office who determined the group of students that took Calculus I as a declared engineering major during the spring or fall 2017. All possible student participants were sent an email asking for participation in the study and to complete a pre-interview survey if they were interested. These are both included in the appendices. Initially, student participation was completely voluntary with no incentive and only three persisters and one leaver responded. After resending the recruitment email two more times, an incentive of a $25 gift card was offered for participation. This provided a large sample of persisters to select from. The results of the pre-interview survey were used to purposefully select the persisters to participate based on their declared major at the time of the Calculus I course to create the most representative sample for that group (Creswell, 2013). The final group of six persisters consisted of three civil engineering, one mechanical engineering, one environmental engineering, and one computer science student. Even with the gift card incentive there was only six leavers that completed the pre-interview survey, so all six people were emailed to participate in an interview. There were only four leavers that responded and completed an interview. The group of four leavers included three declared mechanical engineering and one declared environmental engineering students at the time they took Calculus I.

This resulted in a total of ten interviews which was determined to be an adequate number of students to deeply understand the issues of each student while allowing for saturation to occur. The point at which saturation occurs is not explicitly stated in the literature since it is very subjective to each research project (Guest, Bunce, & Johnson, 2006). However, based on the rough guidelines in today's current literature the use of ten total interviews was considered sufficient. Guest, Bunce, & Johnson (2006) determined that the use of six to twelve interviews allowed their codebook to reach saturation. The addition of any more interviews after the twelfth did not add any new ideas, or codes, to be created proving that all major themes showed up within the 6-12 interview range. Further, Creswell states that it is typical for thematic analysis from interviews to use four or five participants (Creswell, 2013). After completing the analysis, the ten interviews had significant overlap in themes and major experiences that have allowed the desired depth of the problem to be reached. The saturation of the analysis codebook for the six final themes was reached just after the analysis of the first few interviews. The final codebook can be found in the appendix.

3.5.3 Data Collection

The qualitative data collection approach for this study used semi-structured interviews with ten students to uncover the issues with Calculus I and answer the research questions (Creswell, 2013; Yin, 2009). The purpose of using multiple students allows different perspectives to be analyzed on the issue and to also find strength in the similarities of their stories.

The approach was selected for this research because it fits the qualitative analysis criteria laid out by Yin (2003) that includes asking “how” questions, not being able to manipulate the behavior of the participants, and the need to include the contextual conditions in the study. These interviews provide a rich account of real-life situations as a way to address educational problems (Merriam, 1998). This strand of the methodology also allows the development of research to try to improve learning and teaching and offers the researcher the opportunity to learn something about the problem (Case & Light, 2011). These are all relevant to the overall goals of this research project. Finally, as Yin (2003) points out qualitative analysis benefits from using an established theoretical framework as a guide to the study. This supports the use of Tinto’s Institutional Departure Model as the guiding framework for the project.

The data for the portion of this project was collected from students who were registered engineering students at the time they took Calculus I in spring or fall 2017 at an R2: Doctoral University in the Rocky Mountain region. All students in this cohort were reached out to through email to request interest in participating in the study. The email included the description and purpose of the study along with a link to a Qualtrics pre-interview survey. The survey included questions asking about their current/past major, timing of their Calculus I course, and a space to enter an email address to be contacted if chosen to participate. The contact email and survey responses were kept in a password protected document by the researcher to determine which cases would be selected.

There were six persisters and four leavers chosen to interview. Each participant was asked to attend an orientation session with the researcher that lasted no more than 20 minutes where the researcher discussed the purpose of the project, the letter of consent including the procedure and interview protocol used, and provide an opportunity to develop trust with the participant (Patton, 2002; Hancock & Algozzine, 2006; Creswell, 2013). The participant also signed the letter of consent to agree or disagree to being audio recorded during the interview. Following the orientation session, each student participated in a semi-structured interview. The use of a semi-structured interview was chosen as the most appropriate interview strategy to use as it allows the interviewees to express themselves and their own perspective by having the opportunity to explore their responses further (Mason, 2002; Dearnley, 2005; Hancock & Algozzine, 2006). The interview questions were outlined based on the preliminary data analysis and Tinto's Institutional Departure Model (Tinto, 1993) with the intent to understand the student experience in Calculus I and how that influenced a student's academic or social integration into engineering. The interview questions asked about positive and negative experiences in Calculus I and about their peer interactions, faculty interactions, and engineering community definition. The interview protocol is included in the appendix. If the researcher found a particular response interesting or wanted to dive deeper into a participant's answer, then the researcher asked a follow up question to gain a better understanding. The interviews were audio recorded for transcription purposes pending approval of the interviewee. The researcher took notes during the interview which included a reflection following each interview. The reflection was for the researcher to remember any important actions that happened during the interview and to describe the main ideas that were discussed (Stake, 1995). At both the orientation session and the start of the interview, the participant was reminded that participation in the study was voluntary and they could choose to withdraw or have their data withdrawn from the study at any time.

3.5.4 Data Analysis

The data analysis of each student's interview was first done on an individual basis to determine the major ideas of each student's response (Patton, 2002; Yin, 2009; Creswell, 2013). This individual analysis allowed each student to have their own voice and to make meaning of each one (Merriam, 1998). Once each student's interview was coded, there was first the creation of the major themes for each student which was then used to find the overall major themes of all students (Eisenhardt, 1989; Patton, 2002; Creswell, 2013). The analysis for common themes amongst the participants in each of the two groups resulted in six major themes (Patton, 2002; Creswell, 2013). This final analysis establishes which themes were common amongst each group and demonstrates the strengths of each issue. Further, a theme comparison will be done to compare the responses of persisters to the leavers to determine if there are major differences between the two student groups (Yin, 2009).

The use of coding is really the heart of qualitative data analysis (Creswell, 2013).

Coding is the process of summarizing the text into a short phrase that can be used to capture the main idea or feeling of the larger story (Creswell, 2013; Saldaña, 2009). All coding was done in MAXQDA 2018 which is a mixed method analysis software that provides the user with ease of navigation through all included data sources. Coding is a cyclical process, and the goal is to develop a detailed description of each theme (Creswell, 2013; Saldaña, 2009). This detailed description allows others to be able to understand the issues involved in this study even if they have not had these conversations with the students.

Since Tinto's student departure model is so well known in the literature, the use of a priori coding was used to code during the first cycle of coding. This allowed a list of codes to be created prior to any analysis which will provide cohesiveness with the theoretical framework used in this study by using an established language (Saldaña, 2009; Blair, 2015). In combination, the first cycle of coding also used descriptive coding to summarize a section of text in a word or short phrase if no a priori code was appropriate (Saldaña, 2009). Including descriptive coding in the methodology allowed any new topics, not considered in the a priori codes, to become major descriptors of the data. It was anticipated that certain topics would be common amongst persisters and leavers specific to engineering student issues that had not been developed in prior literature, and the researcher did not want to force the data into a pre-established code that it did not fit with (Blair, 2015). This was a hybrid approach used during the first cycle of coding to utilize both predetermined and emergent codes.

The second cycle of coding allowed the first cycle of coding to be reorganized and synthesized together to develop the themes of the overall study (Saldaña, 2009). The use of pattern coding was the primary method for the second cycle of coding. Pattern coding allowed the emergence of major themes and constructs to be developed, and helped establish the causes and explanations for the data (Miles & Huberman, 1994; Saldaña, 2009). This process can be thought as creating a meta-code which contain several codes from the first cycle within each one. These meta-codes were the final themes that are reported in Chapter 4.

3.5.4 Data Validation

The data was verified and validated through several methods. The first method included inter-coder reliability. The method of inter-coder reliability was used to validate the themes and ensure that researcher bias was not a factor. For inter-coder reliability, a codebook was developed that included the six major themes and given to another engineering education graduate student along with one persister interview and one leaver interview. This graduate student coded each interview independently. Once the graduate student completed their first round of coding, the results were compared between the graduate student's codes and the researcher's codes. After the first pass, there was an 86% match on the codes of both interviews which was considered a success for inter-coder reliability. The codes that did not match between the researcher and graduate student were discussed to further refine the codebook and ensure each theme was clear. The final codebook used for this study is included in the appendix.

Once the themes were developed the use of member checking and analyst triangulation was employed as a way to fully triangulate the data. Triangulating the data is a requisite of qualitative coding that uses multiple methods or sources as a way to validate the results (Denzin, 1978; Patton, 2002; Golafshani, 2003; Creswell, 2013; Carter, Bryant-Lukosius, DiCenso, Blythe; & Neville, 2014). First, member checking was used to get external views on the credibility of the results (Merriam, 1998; Creswell, 2013, p. 252, Carter et. al., 2014). The student participants were provided the results for all of the data and asked for feedback. This was done through email and on a voluntary basis. The students were asked to examine the results and provide critical feedback to ensure their stories had been correctly described. As Stake (1995) mentions the participants should "play a major role directing as well as acting in [research]" (p.115).

The second method was analyst triangulation which uses multiple analysts to review the findings (Patton, 2002, p. 556). For this method, all of the engineering advisors were selected because the persistence issue, especially in the pre-professional program, is familiar to them. The advisors were chosen as a strong validation source because they have seen other forms of engineering retention numbers and heard their student's stories, so the nature of the study was well known to them. There were four engineering advisors that were provided the de-identified and aggregated results from the analysis to determine how credible they found the results.

3.6 Integration of Methods

In order to understand the realities of the issues that are facing engineering students in the required math courses a pragmatic lens was used to study the problem on the university scale and at the student level. This dictated the use of a mixed method research design, but the benefit of using this mixed approach is relevant in the blending of the results and story that can be told from it. This strength comes from having both statistical data and personal stories to answer the research questions (Creswell, 2015). The use of this combination allows for development, complementing, and expansion of the found data (Johnson, Onwuegbuzie, & Turner, 2007).

The first integration of the two methods was through the results of the pilot data to be used to inform the interview questions for the qualitative analysis. This integration helped inform the types of questions asked to be more representative of the academic struggles that some students might have experienced. The second integration of results in the study used the final results from both strands in a complementary and expansive way to demonstrate the breadth of the problem statistically and the depth of the issue through the themes found. The lack of engineering student persistence as a result of the required math courses is a known issue, but the statistical model proves the significance of it, and it is the student stories that start to uncover what the issues are. Many of these issues are ones that can be addressed at the institutional level to try to mitigate the problem.

3.7 Limitations of the Study

This study is limited in the population that was included for both strands of analysis. The populations were chosen from a single research university in the Rocky Mountain region. Each population may not be generalizable to other institutions due to the influence by the areas predominant religion, but can provide transferability to the populations of other engineering programs. The statistical analysis was also limited by the available demographic variables that the researcher could obtain and within those there is a substantial amount of data missing for some of the students. The number of students that participated in the interviews was small and may not be representative of the current institution's engineering population. A representative sample could not be created since the participation in an interview was completely voluntary. Also, the students that were interviewed who have left engineering were still enrolled as other majors at the university, so this study does not include the perspective from a student who has completely left the university. A final limitation of the study is that Calculus I may not be part of the reason these students have left engineering, and the reality of all the reasons students may have switched their major is not the focus. This study only looks at the environment of Calculus I and how that may have factored into the student's decision to leave. This will allow other readers to determine the appropriateness of the results to their situation (Kelly & Bowe, 2011; Case & Light, 2011).

3.8 Summary of Research Design

This study used Vincent Tinto's Institutional Departure Model as the theoretical framework and the pragmatic lens of the researcher to create a partially mixed sequential dominant status mixed method research design about the influences of Calculus I on engineering student persistence. The study first implemented a quantitative design through statistically analyzing 13 years of student performance in Calculus I. A logistic regression was created to predict the persistence of an engineering student based on the grade the student received in their Calculus I course, if they had to retake a course, their gender, and their admission scores. The model provides statistically significant results to demonstrate the influence of these independent variables on persistence.

Then qualitative methods were used to interview six persisters and four leavers about their experience in their Calculus I course. The interviews were semi-structured, and the results were coded using a priori and descriptive codes. The final results report on the themes of social and academic integration that developed for these students during their time in Calculus I. The emphasis was placed on reporting these themes, but the third research question was answered through the blending of the results from both approaches. The goal was to use the found results to inform course improvements through the recommendations found in Chapter 6. It is also to begin discussing ways to help these students socially or academically integrate more into engineering during these very early courses.

CHAPTER 4

FINDINGS

The results for this study are reported for each strand of the project, both quantitative and qualitative. These findings will be explained in Chapter 5 along with answers to the study hypothesis and research questions.

4.1 Quantitative Findings

The final data set for the quantitative analysis contained 3,927 student records for first time Calculus I takers. The breakdown by gender and those who were retakers for this data set was reported in Table 1 in Chapter 3. For each analysis procedure, the sample that was used was pulled from the total data set but may have been limited due to missing data for certain variables or the classification of student type that was of interest for that test. The sample used for each procedure is described with each test and the total number of students included in that analysis is also listed. The types of analyses done for this study include both descriptive and inferential statistics. The descriptive statistics categorize the academic characteristics of the population including where the students end up following their enrollment in Calculus I and the grade distributions for those students. The inferential statistics includes a logistic regression model created to predict persistence in engineering based on the independent variables listed in Chapter 3.

4.1.1 Student Majors after Calculus I

The student outcomes within the institution after taking their Calculus I course as a declared engineering major are in Table 4. This includes the entire population from the data set of 3,927 students. There are three major sub-groups this list is comprised of: 1)

Engineering students, those that are still registered or have graduated in engineering (considered persisters), 2) non-registered Engineering students, students that have since left the institution with their last reported major being in engineering (considered leavers), and 3) other majors, students that have switched their major from engineering as categorized by the different colleges at the institution that students have switched to (considered leavers).

Table 5

Student majors following Calculus I course

College	**All students**	**Graduated students (% of total)**	**Students who retook Calculus I (% of total)**
Engineering (EN Grad/Reg)	2006 (51%)	888 (65%)	290 (48%)
Non-registered Engineering (Non-Reg EN)	988 (25%)	-	146 (24%)
Agriculture (AG)	125 (3%)	64 (5%)	29 (5%)
Arts (AR)	16 (<1%)	7 (<1%)	2 (<1%)
Business (BU)	291 (8%)	191 (14%)	46 (8%)
Education (ED)	90 (2%)	52 (4%)	12 (2%)
Human Services (HS)	77 (2%)	45 (3%)	18 (3%)
Humanities (HU)	7 (<1%)	5 (<1%)	2 (<1%)
Natural Resources (NR)	37 (1%)	15 (1%)	10 (2%)
Science (SC)	162 (4%)	83 (6%)	23 (4%)
Undeclared (UN)	128 (3%)	23 (2%)	27 (4%)
Total Number of Students	**3927**	**1373**	**605**

The following figures represent the same data in picture form that shows the breakdown for student majors following Calculus I for all students, for graduated students, and for the students that retook Calculus I at least one time.

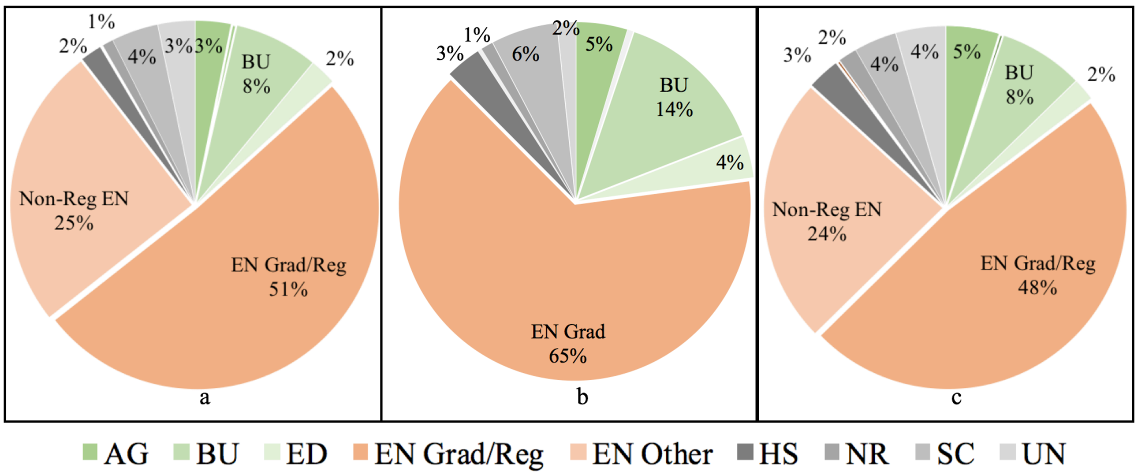

Figure 9. Student majors after enrollment in Calculus I for (a) all students N=3927, (b) graduated students N=1373, and (c) retakers N=605

The table and figure provide evidence that there is a similar trend for both the all student population and the students that have retaken Calculus I. Around 50% of these students are still registered or have graduated in engineering. However, about 25% of these students have left the university all together as noted by the Non-Reg EN group. The remaining quarter of the students have switched to other majors with the largest group transferring into the College of Business. The graduated student chart shows a similar trend but does not include the group of students that are no longer at the university. There is a higher percentage of students around 35% that have switched majors and graduated.

4.1.2 Grade Distribution for Each Student Group

The grades received by the students in each group are categorized in the following table and figures.

Table 6

Grade breakdown for Calculus I (1st enrollment)

Grade	All students	Graduated students	Retakers
A	754 (19%)	322 (24%)	0 (0%)
A-	316 (8%)	149 (11%)	1 (<1%)
B+	328 (8%)	121 (9%)	2 (<1%)
B	484 (12%)	173 (13%)	5 (<1%)
B-	282 (7%)	102 (7%)	5 (<1%)
C+	211 (5%)	70 (5%)	16 (3%)
C	396 (10%)	125 (9%)	34 (6%)
C-	159 (4%)	67 (5%)	28 (5%)
D+	80 (2%)	19 (1%)	50 (8%)
D	225 (6%)	86 (6%)	139 (23%)
F	475 (12%)	101 (7%)	222 (37%)
W	217 (6%)	38 (3%)	103 (17%)
Total Students	**3927**	**1373**	**605**

The following figure represents the grade breakdowns for each group.

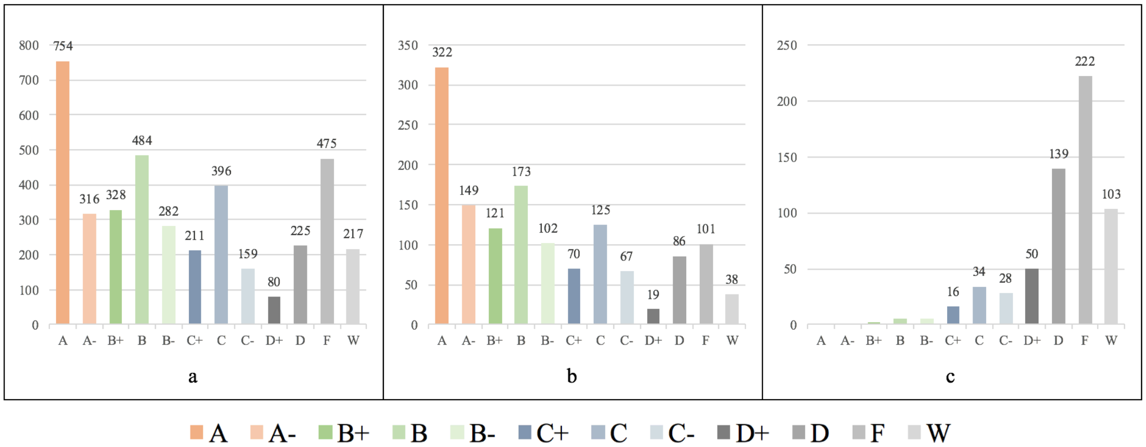

Figure 10. Grade breakdown for (a) all students N=3927, (b) graduated students N=1373, and (c) retakers N=605

The grade breakdown table and figure display that graduated students tend to have higher grades in Calculus I with the majority receiving an A. The students that have retaken the course have D, F, or W grades the first time they took it. The all student group is fairly evenly distributed amongst all grades, the most students still received an A, but there is a large number that received a B, C, or F.

4.1.3 Statistical Analysis

The program SAS System ® was used to analyze various sets of data to determine the significance of the independent variables for persistence in engineering. SAS procedures were used to analyze two different populations of interest: the graduated students and all students (as indicated in Chapter 3 Table 1). The graduated students include only the students that graduated from the university after taking Calculus I as an engineering major. The "all students" group includes the entire data set of students that took Calculus I at the university of interest. There were two different types of analyses done that will be the focus for this section. First, the use of a *t*-test was used to determine if the mean grade for Calculus I was significantly different for persisters and leavers. Next, a logistic regression model was created for each of the two populations of students to determine the most significant factors for persistence in engineering. The detailed results of each analysis is given in the following subsections.

4.1.3.1 Significance of Grade Received in Calculus I

For both groups of students, the graduates and "all students", the mean grade received for each group in Calculus I was used in a *t*-test to determine if there was a significant difference between the persisters and leavers of each group. The grade for the course was reported on a 4.0 scale, where a grade of F=0.0. For the group of graduated students this test included 871 students that graduated in engineering and 464 students that graduated in another major. For the "all students" group this included 1,903 students that are registered or graduated engineering majors and 720 students that are registered or graduated in another major. The students that are reported as absent or not currently registered at the university were not included in this *t*-test comparison. There was found to be a significant difference (α set at 0.05) for the mean grade received in both groups, where the mean grade is higher for the persisters than the leavers.

Table 7

Effect of Calculus I Grade on Persisting in Engineering

Population	N	Mean grade received	Standard Deviation	Equivalent Letter Grade	Significant
Graduated Persisters	871	3.00	1.03	B	Yes <0.0001
Graduated Leavers	464	2.31	1.33	C+	
All Persisters	1903	2.88	1.11	B-/B	Yes <0.0001
All Leavers	720	2.32	1.32	C+	

The following figure includes the grade breakdown for these four groups of students, and also demonstrates the difference in their received grades in Calculus I.

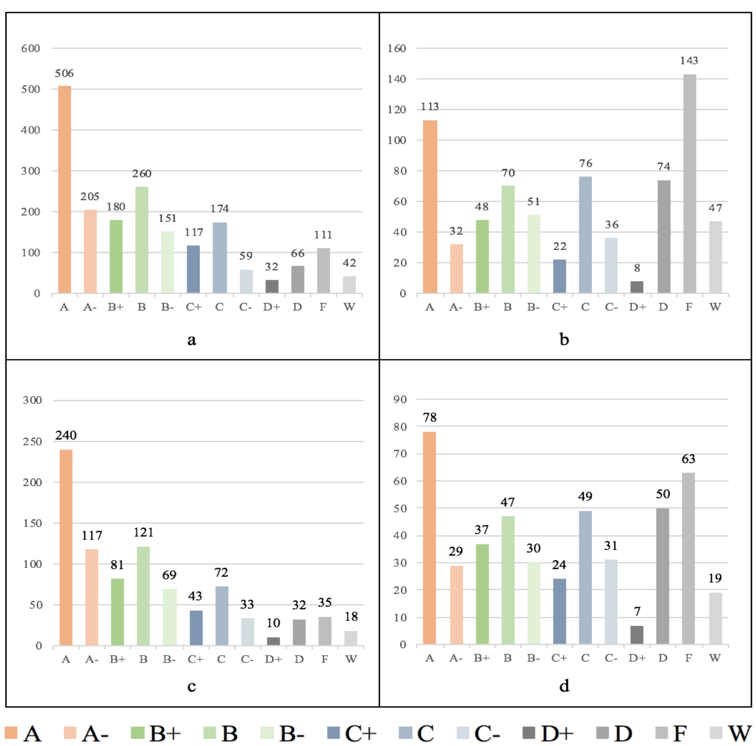

Figure 11. Grade breakdown for (a) all persisters N=1903, (b) all leavers N=720, (c) graduated persisters N=871, and (d) graduated leavers N=464

As expected, the all persisters and graduated persisters have a grade distribution that is skewed towards an A grade. They also have an average grade of about a B in Calculus I. The leavers average a C+ in Calculus I and this is reflected in the grade distribution for both groups of students that shows much higher numbers of students that received a D or F.

4.1.3.2 Logistic Regression for All Students

A logistic regression was run for the “all students” population containing a total of 2,805 observations that had complete data for all variables included in the model. The numbers are broken down by: 1,447 graduated or currently registered engineering students and 1,358 other students (this includes graduated and registered students in all other majors and students who were last reported in engineering but are not currently registered at the university). All independent variables listed in Chapter 3 Table 2 were entered into the model, but only the significant variables were chosen by the stepwise selection process. This allowed for variables to be retained in the model only if they contributed significantly to the accuracy of predicting engineering persistence. The final model for “all students” included only four of the independent variables and is listed in the following table. This model accounts for 67% of the variation in the data.

Table 8

Logistic Regression Model Coefficients for Predicting Engineering Persistence for All Students

Variable	Estimate	Standard Error	Pr > ChiSq	Odds Ratio Point Estimate
Constant	0.547	0.306	0.074	-
Calculus I Grade	0.631	0.041	<0.0001	1.880
Retaker (N reference)	-0.931	0.142	<0.0001	0.394
Gender (F Reference)	-0.523	0.115	<0.0001	0.593
ACT Math	-0.045	0.012	0.0001	0.956

This table represents a model that can be used to predict persistence in engineering. The interpretation of the model is best done using the reported odds ratios. For example, for every Calculus I letter grade increase a student receives they are 1.88 times more likely to persist in engineering (holding all other variables constant). Conversely, if a student has to retake Calculus I then they are 0.606 times less likely to persist in engineering, or if the student is a female, they are 0.407 times less likely to persist. These numbers imply that females who have to retake the course are at a significant disadvantage to their counterparts. The final variable of ACT Math has a counterintuitive result since the estimate is negative and odds ratio is below one. This implies that as ACT Math score increases then the likelihood to persist decreases. However, considering the requirements to even register as an engineering major that have already set a high threshold for ACT Math score, and the odds ratio estimate being almost nearly one this variable should not be taken separate from the model but only a significant variable to use with the entire model.

4.1.3.4 Logistic Regression for Graduates

A logistic regression was run for the graduate student population containing a total of 914 observations that had complete data for all variables included in the model, where 572 are engineering graduates and 342 are graduates in other majors. All independent variables listed in Chapter 3 Table 2 were entered into the model, but only the significant variables were chosen by the stepwise selection process. This allowed for variables to be retained in the model only if they contributed significantly to the accuracy of predicting engineering persistence. The final model for the students that graduated also included only four of the independent variables and is listed in the table below. This model accounts for 70% of the variation in the data.

Table 9

Logistic Regression Model Coefficients for Predicting Engineering Persistence for Graduates

Variable	Estimate	Standard Error	Pr > ChiSq	Odds Ratio Point Estimate
Constant	2.552	0.864	0.003	-
Calculus I Grade	0.744	0.084	<0.0001	2.104
Gender (F reference)	-0.929	0.200	<0.0001	0.395
Retaker (N reference)	-0.938	0.263	0.0004	0.392
HS GPA	-0.828	0.247	0.0008	0.437

The logistic regression model for students that have graduated from the university looks similar to the all student model. There were four significant variables that were included, three were the exact same with the exception of the fourth variable which was

HS GPA. This model had a higher odds ratio for Calculus I grade, where for every letter grade increase in Calculus I grade a student is 2.1 times more likely to graduate in engineering. Also, for this model gender was more significant than retaker, but the same trend holds true that a female who has had to retake the course is significantly less likely to graduate in engineering than their counterpart.

The final variable of HS GPA is different from the use of ACT Math in the all student model, but has a similar counterintuitive result. However, the odds ratio estimate is not close to one in this case requiring further investigation. The explanation for the negative estimate of HS GPA can be explained by two likely phenomena. The first consideration is based on considering HS GPA as rational data which means it is considered a continuous variable where the distance between each adjacent value is exactly equal. In a numerical sense for grades this may be true, but when considering how many teachers actually assign grades, it is likely that the consideration of going from a D to a D+ is not the same as going from an A- to an A. This will actually skew the data which was not taken into consideration when building the model. The second consideration is that high school GPAs are not all equal, are sometimes self-reported, and can be considered a very subjective measure depending on how they have been reported (Kuncel, Crede, & Thomas, 2005; Geiser & Santelices, 2007). The reason it is still included in the model is the same as the reason to include ACT Math score in the previous model, this variable proved to be significant in predicating persistence for the large population that was used and should only be considered in use with the model as a whole, which accounts for 70% of the data.

4.2 Qualitative Findings

The qualitative findings from the student interviews resulted in six major themes. Four themes were developed using a priori coding and the remaining two themes emerged from the use of descriptive coding. The qualitative results are reported by describing each theme, the main ideas included in the theme, and the frequency counts for each idea. The use of frequency counts for each main idea highlights the differences in comments made by persisters and leavers.

4.2.1 Thematic Analysis

The use of a priori codes from Tinto's Institutional Departure Model guided both the creation and analysis of the interview questions. As a result, four of the six final themes are the formal and informal types of academic and social integration a student experienced while in Calculus I. The remaining two emerging themes were still relevant to Tinto's model, and developed because many of the student interview responses were not relevant to the four a priori codes. There were no interview questions created to target the types of comments that fit with these two themes, but they still emerged as very important factors that affected the student experience in Calculus I in addition to the a priori themes. The first emergent theme was personal reasons for both staying and leaving the institution which is a part of Tinto's model in the Goals/Commitments section. The types of comments that were relevant to this theme include the student's intention for the engineering degree program, their personal feelings about engineering, and their commitment to engineering. The second emergent theme was institutional/college factors and is not explicitly part of Tinto's model, but surprisingly came up in the student interviews enough times to necessitate making it a theme. Tinto's model includes institutional factors through the academic and social constructs, but did not consider the logistics of setting up courses or creating a degree path. The fit of this final theme into Tinto's model will be shown at the end of this chapter with a new modified conceptual model, but it is an important factor to consider in student persistence because it results in major effects for the academic system and part of the social system.

The final six themes that were found from the qualitative analysis include formal academic integration, informal academic integration, formal social integration, informal social integration, personal reasons, and institutional/college factors. Within each theme there were positive experiences and negative experiences expressed from both the persisters and leavers. The results are documented to include the description for each theme along with a table that shows the positive and negative experiences the students described for each theme and the number of persister and leaver interviews that included each experience. While analyzing the interviews, there was a clear juxtaposition between the student's experiences, some spoke of their Calculus I experience in a positive sense and some were in a negative sense. As a result, within each theme the positive and negative experiences were separated, where a positive experience allowed the student to connect more within engineering or the engineering community and a negative experience did not.

4.2.1.1 Formal Academic Integration

The theme formal academic integration includes the formalized components of Calculus I including academic performance and content delivery. This theme involves any mention of the student's academic performance, their understanding of the course content, their ability to learn the material, the application of the material to other courses, and any previous knowledge needed for Calculus I. Students expressed both positive and negative formal academic integration experiences.

The positive experiences focused on the student feeling prepared for the concepts they learned in Calculus I, successfully completing the course, or gaining skills from the course that they could use in future courses. Many of the interviews suggested that students valued having a prior introduction to calculus concepts through previous high school or college coursework including taking pre-calculus classes to review the concepts before jumping into calculus. A persisting student mentioned, "I had to retake [the pre-calculus courses], which I was super disappointed at the time, but going into Calculus I ended up being a huge help" (Participant 2, Persister, Female). Another common idea that came up more than anticipated was the number of students who had taken AP Calculus in high school but still took Calculus I at the university. A student that ended up leaving engineering commented, "I hadn't taken math in two years, but I had taken AP calculus before, and so I felt like I had a better foundation than most people in the class" (Participant 3, Leaver, Female).

There were much fewer negative formal academic integration experiences and they included the students feeling unprepared for Calculus I and the material covered in the course or not seeing the connection between the concepts of Calculus I with later courses. A persisting student commented, "I would like to learn a little bit more about why calculus is important in engineering, more examples relevant to engineering and why it's important" (Participant 1, Persister, Male). Similarly, a leaver said, "The first time taking Calculus I, I had absolutely no clue how the concepts applied to engineering and physics as a whole, it just looked like a bunch of formulas to me" (Participant 10, Leaver, Male). It was often mentioned that they did not feel what they learned in Calculus I connected to their following courses whether that was a math, science, or engineering course.

Table 9 depicts all the main ideas included in the theme formal academic integration from the student comments. These are sorted by positive and negative experiences along with the number of interviews that mentioned each idea. All 10 interviews mentioned some form of formal academic integration.

Table 10

Main Ideas for Formal Academic Integration

Positive	**Persisters**	**Leavers**
Calculus I prepared student for their next math/science course	4	3
Previously took AP Calculus	2	3
Above average course grade (B- or higher)	3	1
Enjoys problem solving	2	2
Useful exam reviews	1	2
Calculus I prepared student for the required workload in engineering	2	1
Benefitted from taking lower math courses first	2	1
Negative		
Not prepared for Calculus I from previous math	2	1
Hard exams	1	2
Calculus I did not prepare student for subsequent courses	1	1
Wanted engineering applications in Calculus I	1	1
Did not have time to review the math foundations needed for Calculus I applications	1	1

As documented in the table, the majority of the students mentioned that Calculus I prepared them for their next math or physics course, but very few mentioned feeling prepared from Calculus I for an engineering course. The remaining formal academic integration ideas were mentioned by much fewer students but at least one persister and one leaver mentioned each one.

4.2.1.2 Informal Academic Integration

The theme informal academic integration includes the less formalized student-to-superior interactions during the student's semester in Calculus I. This theme involves the interaction with any faculty, teaching assistants, tutors, advisors, or other college staff they had about engineering or their Calculus I experience during their semester in Calculus I. Any interaction with a person that was not a direct peer of the student would be considered informal academic integration if the interaction was relevant to the course. The instructors teaching style was also an important factor of this theme. The students made both positive and negative comments about their informal academic integration.

The positive comments focused on the instructor's style for both teaching and course set up along with having positive interactions with advisors and other faculty relevant to Calculus I. For example, a student that has since left engineering mentioned that, "What helped the most was that [the instructor] was frequently available for office hours and encouraged us to meet with him after class and before class and always be available with any questions" (Participant 10, Leaver, Male). A persisting student stated that, "[My instructor] did a really good job of explaining things and slowing things down that weren't easy to understand, especially in office hours" (Participant 1, Persister, Male).

One leaver also had valuable interactions with their advisor while in Calculus I, where the advisor provided resources and places for the student to receive help in the course.

The negative comments for informal academic integration pertain to advising, instructor style, and a lack of connection to engineering resources. The use of “negative” to describe these main ideas does not imply that the advising was bad or the math tutoring center is not adequate, but the use of “negative” simply means that they did not support an integration between Calculus I and engineering. The students all expressed having a good interaction when they went to their advisors, but the majority of advising appointments focused on registration of the student for the next semester. Some of the students expressed concern about approaching their advisors about the math courses due to the advisor’s background. One persisting student stated that, “It’s harder [advising] the math classes because they don’t know the professors and there are so many different professors in the math department” (Participant 1, Persister, Male). A leaver commented that, “I just felt like I wanted to talk to someone that had like been there, done that kind of thing” (Participant 3, Leaver, Female). In addition, students felt that there was a lack of connection to engineering faculty while they were in Calculus I. A student that left engineering responded to being asked about interacting with an engineering faculty member, “An engineering instructor? I don’t even know if I knew one” (Participant 7, Leaver, Female). Similarly, a persisting student echoed the same idea, “I didn’t really have any engineering instructors at that point” (Participant 2, Persister, Female). All these negative informal academic integration comments show that student’s felt there was a major lack in an authority figure that could support them academically during this very early stage in their engineering degree.

The main ideas of this theme are broken down to demonstrate the positive and negative interactions that students are having with faculty, staff, and tutors during Calculus I. These ideas are listed in the following table along with the number of interviews that mentioned each idea. All 10 interviews mentioned some form of informal academic integration.

Table 11

Main Ideas for Informal Academic Integration

Positive	**Persisters**	**Leavers**
Teaching style facilitated learning	5	3
Instructor provided resources	4	2
Utilized office hours	4	1
Received helpful and relevant resources from advising	3	1
Personal connection with instructor	2	0
Homework was assigned weekly	1	1
Reached out to get an engineering perspective	0	1
Used the engineering tutoring center	0	1
Negative		
Advising not relevant to Calculus I	5	3
No interaction with engineering faculty	4	3
Instructor was confusing or negative	0	4
Approach instructor primarily through email	2	2
Used the math tutoring center over engineering tutoring center	2	2
No initial advising when first registering for courses	1	1
Did not approach instructor	1	0

The majority of the informal academic integration comments were relative to each student's specific Calculus I instructor or assigned advisor, and the students generally mentioned that their instructor for Calculus I helped them learn and they never discussed Calculus I with their assigned advisor. The most interesting result for informal academic integration is that all leavers commented on having a negative or confusing interaction with their instructor, some were single instances and some lasted throughout the semester. None of the persisting students mentioned any type of negative interaction with their instructor.

4.2.1.3 Formal Social Integration

The theme formal social integration includes the formalized extracurricular activities students can get involved in at the university. These types of activities include student clubs and student organizations either through the College of Engineering or through another group at the institution. The majority of student comments indicate that the students were involved with groups outside of engineering or did not feel as though they had the resources to get involved.

The only positive comments for formal social integration came from the few students that were involved in a club but they were all non-engineering clubs. This is a positive because the students are integrating into the university socially, but these integrations are not explicit to engineering. The students expressed the value they found in being part of a club, but none mentioned interest in an engineering club at that time.

The comments for formal social integration were primarily negative implying that students did not see the value or were not even aware of clubs and student organizations at this point in their degree. There was a common answer of "No" when asked if the student was involved in an engineering student club or student organization during the semester they took Calculus I. A leaver said, "I could join a club, but a club costs money, and it costs time, and everything" (Participant 10, Leaver, Male). A persisting student said, "I wasn't very aware of different clubs or anything, I think I might have heard about like one" (Participant 5, Persister, Male). Further, several other students stated reasons like work or social anxiety preventing them from getting involved. This is another area that students felt they lacked during their time in Calculus I.

The main ideas for formal social integration are listed in the following table along with the number of interviews that mentioned each one. All 10 interviews commented on their experience with formal social integration.

Table 12

Main Ideas for Formal Social Integration

Positive	**Persisters**	**Leavers**
Participated in a non-engineering club	3	1
Negative		
Not aware of opportunities to get involved	4	2
Time prevented involvement	3	3
Hesitant about fitting in	3	1

The main ideas for formal social integration include the majority of students not knowing about opportunities or feel they had the time to get involved during the semester they took Calculus I. The student quotes also echoed this.

4.2.1.4 Informal Social Integration

The theme informal social integration includes any interaction the students had with their peers inside and outside the classroom relevant to the course. This includes creating student study groups, meeting up with students outside of class to work on homework, or interacting with other students during class time. The types of informal social interactions that the students experienced ranged from formalized study groups to face recognition when passing in the hall. However, most of the interviewees felt that they were not given the opportunities to connect with other engineering students in Calculus I even though the course is required of all engineering students.

The positive informal social experiences that students had in Calculus I included the ability to begin to see familiar students in that course and around the engineering buildings. A persisting student stated, “It’s definitely one of the first classes that a lot of the same people take at the same time, like sort of like a gateway class” (Participant 5, Persister, Male). Another persister also echoed, “In all my classes, I definitely see the same people consistently and I’m sure they are in my major” (Participant 6, Persister, Female). Additionally, a student who left engineering mentioned that because of Calculus I, “I could point out faces” (Participant 3, Leaver, Female). This shows that Calculus I is one of the first courses that engineering students can start recognizing each other, which for some was used as an opportunity to create study groups that helped them succeed. The study groups were all formed organically and the majors of the students were not a consideration. A student still in engineering mentioned, “I got pretty lucky I think… someone passed around a sheet and whoever wanted to be in a study group wrote their name down" (Participant 4, Persister, Male). It was not a formalized process and completely student driven to form that study group, but the group allowed the student to succeed even though not all members were in engineering. A leaver stated, "I had a study group. We formed it ourselves… other than that we didn't really have any communication with the rest of the students" (Participant 9, Leaver, Female). All the students that formed study groups echoed this idea that the groups allowed students to have social interactions with the other students in their class that the lecture or recitations did not provide.

Conversely, the students that did not get involved with a small study group mentioned that it was because they felt they had different study habits or it was too challenging to try to find other students interested in studying together. A leaver mentioned, "I didn't really have the opportunity to [connect], not that I wasn't trying to, I just didn't know how to. To be honest, it felt like I was the only one in the class" (Participant 10, Leaver, Male). A persisting student when asked about working with engineering students during Calculus I said, "I thought for sure that I would connect with [other engineering students] and we'd work together, but we hardly ever did" (Participant 1, Persister, Male). Another persister commented, "I'm trying to remember if I even remember people from that class. I don't know if I really remember making that many relationships in that class" (Participant 8, Persister, Male). This idea demonstrates the lack of social interaction that Calculus I provides for the engineering student population. However, some students that did not form connections are fully aware that it was themselves that prevented it from happening, as one persister mentions, "I didn't really interact much with other students. I would pretty much just go, listen, go home, and work on homework" (Participant 5, Persister, Male). Another idea included in negative informal social integration was the forming of connections to engineering students through other courses besides Calculus I. This is categorized as a "negative" idea because it is not fostering the integration between Calculus I and engineering, but the researcher acknowledges that it is positive for students to have that experience from other courses. For example, a persister said, "I took a surveying class as well that semester, so I made friends with a lot of [engineering students] through that" (Participant 4, Persister, Male). A leaver said similarly, "I met a few people in surveying during that semester, but I felt like I met more people when I was in Calculus II" (Participant 3, Leaver, Female). This main idea points to the challenge most of the students had to feel socially integrated with the engineering student community during the semester they took Calculus I.

All the main ideas for informal social integration are listed in the following table along with the number of interviews that commented on each idea. All 10 interviews mentioned some form of informal social integration.

Table 13

Main Ideas for Informal Social Integration

Positive	Persisters	Leavers
Formed Calculus I study groups to work on homework	4	2
Started to recognize other engineering students from taking Calculus I	3	2
Engineering student community started to develop	3	1
Recognized the diversity of the engineering student population	2	1
Negative		
Did not connect with engineering students in their Calculus I class	5	4
Connected through the common struggle of their classes	4	1
No way to connect to engineering students outside of Calculus I during that semester	1	2
Connected with engineering students through other courses (not Calculus I)	2	1
Difference in student study habits led to a lack of connection	2	1

The table of results for formal social integration provide evidence that many students formed study groups and valued these study groups, but these groups were not necessarily made up of engineering students or help facilitate interaction between engineering students. Calculus I was a valuable course to begin recognizing other students and start to see what the engineering community could be, but outside of the course many of the students did not feel an engineering connection yet.

4.2.1.5 Personal Reasons

The theme personal reasons emerged in the analysis because students would mention personal reasons for why they became an engineering major or why they pushed through Calculus I. Anything that happened outside of the course, the university, or the student's social circle were included in this theme like a student's external support system, personal desire, or personal injury. There were no interview questions directed towards personal feelings or motivations, but many of the student's brought up personal reasons during the interview if they felt it was important to discuss relative to their experience in Calculus I. The personal reasons caused students to have both success as a result of them or failure in the course, which is why there are positive and negative main ideas reported.

The positive reasons that came up in the interview focused on excitement about engineering and the desire to become an engineer because it is such a prestigious field. A leaver said, "I knew [engineering] was really hard and that's why I wanted to do it, it was almost like a pride thing" (Participant 3, Leaver, Female). A persister described engineering students as, "Some of the hardest working students, and the smartest, and I wish I could be like that" (Participant 4, Persister, Male). These reasons motivated the students to continue through Calculus I to get to the engineering curriculum.

The negative personal reasons include the idea that students knew they just had to get through Calculus I to pursue an engineering degree, but otherwise did not value the course. A leaver described getting through Calculus I as, "Essentially like the big push to get to the other side with all of us and we had a common goal" (Participant 7, Leaver, Female). Another leaver mentioned that they received the following advice about Calculus I, "Just push through the course and you'll get into one that you like" (Participant 3, Leaver, Female). Additionally, interviewees mentioned a variety of other personal issues, injuries, or external commitments that factored into their experience in Calculus I that were also included in this theme. The external commitments included students that were working close to full time and religious commitments.

The main ideas for personal reasons are listed in the Table 13 along with the number of interviews that mentioned each idea. Personal reasons were mentioned in eight of the interviews.

Table 14

Main Ideas for Personal Reasons

Positive	**Persisters**	**Leavers**
Interested in the degree because of the prestige of engineering	2	2
Excited about learning engineering	1	2
Negative		
Motivated to just get through Calculus I to get to engineering	2	3
Personal issue conflicted with learning	2	2
External commitments	1	2
Calculus I did not make engineering seem attainable	1	0

As expected, the personal reasons students mentioned were all unique, but the most common one was the idea that Calculus I was just a course to get through in order to move on in engineering. Many of the participants were not interested in engineering for the Calculus I requirement but saw it as a stepping stone to get to the actual engineering coursework. There were some students that had personal issues come in the way of their learning, which could have factored into their departure from engineering more so than their Calculus I experience.

4.2.1.6 Institutional/College Factors

Institutional and college factors emerged as the final theme because students would describe certain aspects of their Calculus I course that cannot be controlled by the students, faculty, and staff that they would interact with day-to-day during the course. This theme includes ideas like the logistics of the course or how the course was offered to the students. These factors are all relative to factors that the Department of Mathematics, College of Engineering, or the university control based on scheduling and policies. They were brought up during the interviews as areas that both helped and hurt the student during their time in Calculus I.

The only positive for this theme was the mention of taking a Calculus I course that included a recitation section, which was only mentioned by four out of the 10 interviewees. The recitations ranged between 25%-40% of the in class time the student spent in Calculus I, the remaining time dedicated to a traditional lecture typically with a large class size. All the students that brought up the recitation section said it was led by a teaching assistant that differed from the instructor of the lecture section. A student that has left engineering said, “I did feel more connected to the [students] in the recitation because I felt like it’s easier to approach 20 people than it is to approach 300” (Participant 7, Leaver, Female). A persister echoed this same feeling by saying, “We had the recitation which we were able to get the personal help… when it’s smaller you feel like you have more time with the teacher” (Participant 6, Persister, Female). The consensus was positive for the recitation sections, mainly describing the smaller class size which allowed more interaction with both students and the instructor.

The negative institutional/college factors included two main ideas: 1) the logistics of the course like the time, location, or class size, and 2) having Calculus I as such an early requirement in engineering detached from taking any engineering courses. It was unexpected that several students brought up issues with the logistics of the course location including lack of windows in the room, noisy distractions from other classrooms, and classroom size was too small to accommodate the enrollment number. However, the most common idea was the lack of connection of Calculus I to the engineering degree program, as mentioned by almost all of the interviewees. A persister said, “Very few connections were made while I was in calculus to the engineering college or any engineering programs” (Participant 1, Persister, Male). Additionally, another persister said, “I was still kind of in a lot of general classes, so it felt like I wasn’t really part of my department” (Participant 8, Persister, Male). A leaver said that Calculus I was, “not really beneficial or offer insight into the engineering community or anything like that” (Participant 10, Leaver, Male). The only mention of connection to engineering was described by a leaver who said “[Calculus I] at least brought me back into the engineering building to be able to feel like I was an engineer almost” (Participant 3, Leaver, Female). However, it was clear that the early placement of the course did not facilitate any connection to engineering.

All these ideas are listed in Table 14 along with the number of interviews that commented on each one. All 10 interviews brought up at least one institutional/college factor.

Table 15

Main Ideas for Institutional/College Factors

Positive	Persisters	Leavers
Calculus I course included a recitation	2	2
Negative		
Calculus I lacked a connection to the engineering discipline	5	4
Large lecture course	2	4
Bad location for the course	3	1
Did not meet expectations of engineering	1	1
Lack of consistency amongst Calculus I courses	0	2
Expensive book	0	1

The majority of the participants agreed that the placement of Calculus I in the engineering degree program along with the other logistics of the course kept it from allowing the students to connect to engineering. The course was seen more as a general studies course that caused a roadblock on their way to progress through engineering.

4.3 Data Validation

The use of member checking as described in Chapter 3 was used to make sure the student participants thought the results accurately portrayed their experience. Only two of the 10 participants responded with feedback and both said the results accurately portray what they think students are going through in Calculus I. The only criticism received was not highlighting personal issues enough; the student thought those issues can majorly impact the student success in any course at any time. As a result, all the interviews were read through again to ensure that all personal issues that came up during the interviews were included in the results.

The other method used for validation was an analyst triangulation session which included the engineering advising staff. This group was selected as the most relevant and knowledgeable on the issues students face with deciding to persist or not. There are four advisors for engineering and all four were emailed the results. Only two of the four advisors provided feedback. Both advisors agreed that the results portray what they expected from the social integration side, but were surprised by some of the responses for academic integration. One of the advisors mentioned that some of the negative academic integration statements may differ now with the introduction of some of the freshman engineering courses and based on a student's engineering major. The major criticism from the advisors is the small sample size because there was not representation for all engineering degrees within the students interviewed. This was an unfortunate limitation of this study, but the advisor stated that the results were still very insightful.

4.4 Conceptual Model

The results from the student interviews align closely with Tinto's model (Tinto, 1993) except for the addition of the final emerging code. An adapted conceptual model has been created to show where all the themes including the institutional/college factors can fit with the original model.

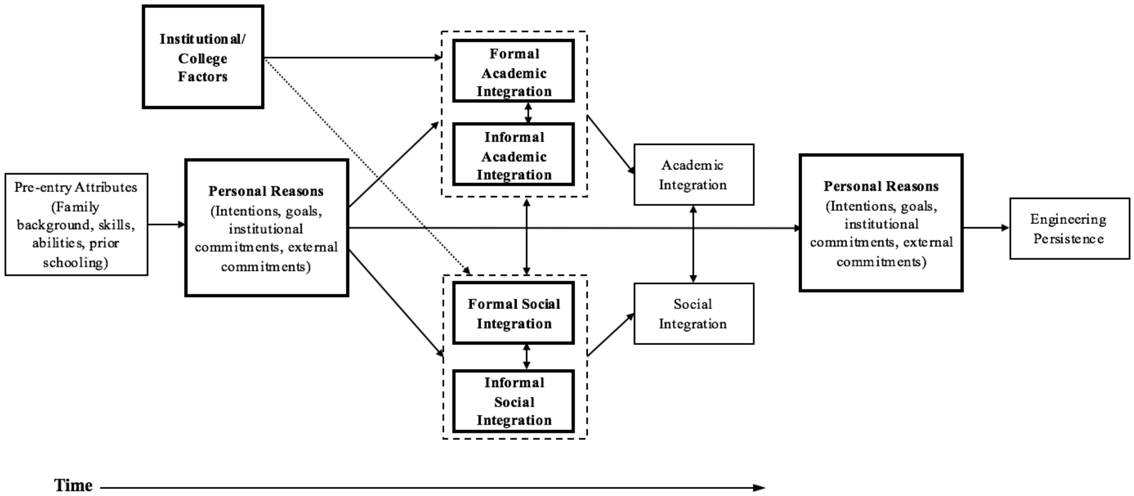

Figure 12. An adapted conceptual model

This adapted model contains all the same elements as Tinto's original model (Tinto, 1993) with the addition of the Institutional/College Factors. The *Pre-entry Attributes* were combined and are now represented as a single element at the start of the model. The original column labeled *Goals/Commitments* was combined into a single element and labeled Personal Reasons based on the theme name found from this analysis. The Institutional/College Factors was added to the model slightly ahead of Personal Reasons since these factors affect the type of course offering, other logistics, and happen very early on in the timeline of the course. Institutional/College Factors can affect both the academic and the social system and as result end up affecting a student's Personal Reasons. Institutional/College Factors has a direct effect on the academic system as noted by the solid arrows pointing at those elements. The direct effect of Institutional/College Factors on the academic system include the lack of consistency amongst Calculus I sections, the instructor assigned to specific courses, the classroom location, the assignment of student advisors, and the staffing of tutoring centers. All of these were major ideas that came up for formal and informal academic integration, but the origin of the issue can be linked back to the responsibility of the college or institution as a whole. The effect of Institutional/College Factors on the social system is not direct, as noted by the dotted arrow, but the largest influence it has on that system is through the set-up of the course. If the course is set-up to promote student interaction (e.g. a recitation course) or take place in a classroom that allows students to easily interact then students were more likely to express positive informal social integration experiences.

These results confirm that the elements of Tinto's model are all important to consider in engineering student persistence with the addition of the Institutional/College Factors. The model now represents a longitudinal model (either over the course of a semester or the entire academic career of a student), but the external logistics of both the course design and the degree requirements factor into how students integrate in the degree program especially for engineering. The exclusion of this theme from Tinto's original model allows these factors to be easily overlooked by institutions when using this model to understand student departure. The importance of this addition will be discussed in detail in the next chapters.

CHAPTER 5

DISCUSSION

The chapter will discuss the results of the study through answering the research questions and hypothesis. First, the quantitative results will respond to the hypothesis, then the qualitative results will answer research questions 1 and 2, and finally the results from both methods are integrated to answer research question 3. The first and second sections of this chapter only look at discussing quantitative results or qualitative results individually to demonstrate the importance of each strand in understanding the problem, but it is the integration of both methods that provides the bigger picture of how Calculus I helps students integrate into engineering.

5.1 Academic Performance and Engineering Persistence

The hypothesis for the quantitative strand of this analysis was:

> H1: The academic integration of an engineering student as measured by academic performance in Calculus I is correlated with their persistence in the engineering degree program.

To test this hypothesis, the academic performance of student data over 13 years was analyzed to understand the academic performance breakdown for different student groups and identify statistically significant factors to predict persistence in engineering.

As discussed in the literature review, there is agreement that many students who start in engineering do not actually graduate in engineering, so it was important to determine the actual number of students that leave engineering after taking Calculus I and where those students are going. Figure 9 represented the breakdown of where students end up after taking Calculus I at the university for all students, the graduated students, and the students that had to retake the course. The percentages are similar for all three populations. This confirms the literature that only about 50% of students that start out as declared engineering majors remain in engineering (Fortenberry et. al., 2007; Ricco, Ngambeki, Ling, Ohland, and Evangelou, 2010; Ohland et. al., 2004; Litzler & Young, 2012; National Academy of Engineering, 2005; American Society for Engineering Education, 2016). The 50% includes students from the data set that have graduated and those that are currently still registered in engineering. The remaining 50% of students is split between students that leave the university and those that switch their major. It is very concerning that 25% of the students that start in engineering end up leaving the university altogether. This significant number of students that leave the university after being declared an engineering major has not been reported in the prior literature. However, it is hard to speculate as to why this many students do not continue on in their education due to the large variety of reasons students have, but the lack of academic and social integration is likely to factor into it. The remaining quarter of students that switch majors is also likely to have had a lack of integration into the engineering major in addition to the variety of personal reasons that students change.

The grade distribution also shows an interesting trend specifically for retakers. As expected, the students that retake the course have primarily D, F, and W grades their first time through; however, of the students that had to retake the course, 48% of them were successfully able to retake and pass the course to continue on in engineering. Further, this same figure shows that the students that have graduated, Figure 10b, has a larger percentage of higher grades with very few D, F, and W's. This similar trend is also apparent in Table 5. This table shows the mean grade comparison for all students and for the graduated students, and there is a significant difference between the mean grade received by engineering persisters compared to leavers for both groups. The persisting students receive an average grade of a B in Calculus I while the leaving students receive an average grade of C+. From this comparison, it can be speculated that a poor grade in Calculus I does not properly prepare students for the following courses resulting in them leaving the major. The lower grades can impact the student's formal academic integration into engineering thus preventing them from integrating into the degree.

5.1.1 Student Persistence for All Students

The final logistic regression model for the entire student population included four of the independent variables. The most significant variable was the grade a student received in Calculus I, followed by whether the student retook the course or not, their gender, and their ACT Math score. This supports the other models that have been created that use gender and college entry scores as meaningful predictive measures for engineering persistence (Moses et. al., 2011; Jin, Groll, Imbrie, & Reed-Rhoads, 2011; Felder et. al., 1994; Bernold et. al., 2007).

Therefore, the model as a whole can be useful to help predict students that are at-risk for engineering persistence based on their received grade in Calculus I, whether they retook the course, their gender, and their ACT Math score. This model could be valuable to institutions to allow the ability to predict at-risk students early on in their engineering career. By doing this there is the potential to increase retention numbers by providing these students with the proper type of support they need prior to deciding to depart from the degree program. The support that could be valuable for these at-risk students is presented in Chapter 6.

5.1.2 Student Persistence for Graduated Students

The logistic regression model for graduated students looks similar to the previous model, but this model had a higher odds ratio for Calculus I grade, where for every letter grade increase in Calculus I grade a student is 2.1 times more likely to graduate in engineering. This higher odds ratio shows that students that graduate from the university are slightly different from students that are still registered since those students may not actually graduate. This higher odds ratio implies that the Calculus I grade that graduated students have received is a good predictor of graduation in engineering over graduation in another major.

The inclusion of ACT Math and HS GPA in the two models represents that pre-college attributes are still important to consider for a student in college. The use of ACT Math in the all student model over HS GPA indicates that it may be a better predictor for engineering persistence for students that are earlier in their career, and HS GPA is a better predictor for long term persistence that culminates in graduation of the student. This subtle difference reinforces the idea that not all pre-college attributes are valuable for all college prediction models (Tyson, 2011).

5.1.1 Does Academic Performance Predict Persistence?

As these models show, academic performance or the grade a student receives in Calculus I is a good predictor of persistence in engineering. This confirms prior literature that the grade a student receives is extremely important for their persistence (Cabrera, Nora, and Castaneda, 1993; Middleton et. al., 2015). This is an expected result, but the magnitude of significance has now been documented. In both models, the Calculus I grade had an odds ratio around two, significantly more than any other variable, suggesting that the grade a student receives in this initial required course can have a major impact on the rest of their academic career. These models further validate the importance that grades play in academia and specifically engineering, but do not explain the full picture of the Calculus I experience.

5.2 Academic Integration and Calculus I

The first research question for the qualitative strand of this analysis was:

1. How does an engineering student's academic integration develop during Calculus I?

To answer this research question, several interview questions were created that focused on academic integration in Calculus I and two academic integration a priori codes were used in analyzing the interview data. The results from the formal and informal academic themes compliment the quantitative analysis that showed that academic performance could be a predictor for persistence. There were not major differences between the responses from persisters and leavers for formal academic integration and only one subtle, but explanatory difference for informal academic integration.

5.2.1 Formal Academic Integration into Engineering

Much of the formal academic integration in Calculus I was positive. Students felt as though the course prepared them for their following courses. The two most surprising results were the lack of comments about having more connection in the course material to engineering and the number of students that took AP calculus or pre-calculus courses prior to Calculus I. It has been speculated that many students want the material of Calculus I to have more application or examples relevant to engineering (Wilcox and Bounova, 2004; Guner, 2013; Dunn, Loch, and Scott, 2018). Only two out of the 10 interviews mentioned the desire for this. The remaining interviews did not bring up the concepts or applications of the Calculus I material but focused on how the material prepared them for the following courses. While the number of interviews were limited, this result contradicts much of the literature that states that engineering students want Calculus I content to include more engineering applications (Venable et. al., 1995; Budny et. al., 1997; Ohland et. al., 2004; Guner, 2013). This idea was not echoed in the participant's comments, instead they emphasized a desire for the Calculus I course to start providing connections to the engineering community not necessarily through course material but through student interaction, registration, course instructor, course location, and other ways of integrating math and engineering.

Further, half of the students mentioned that they had taken AP Calculus in high school but ended up in Calculus I in college because they did not receive the adequate score on the AP exam or they wanted the review before jumping into Calculus II. Even with previous exposure to the material they were all in agreement that it was valuable to have seen the material before and to experience the course in the college setting again. There were several other students that had to take the pre-calculus courses that the college offers before being able to enroll in Calculus I due to a low math placement score. These students mention that at first they were disappointed in having to take these courses, but ultimately it allowed them to be more successful in Calculus I because they felt better prepared for the content and workload. Even with the delay this caused for taking Calculus I, none of these students mentioned that being a concern to them, but were all positive about taking these pre-requisites. These two examples represent how important math readiness is at being successful in the required math courses. Students that felt they should be ready for Calculus I or even Calculus II but did not have scores to reflect that ended up appreciating the experience to review previously learned material in a college setting before moving on to the other math courses. Math readiness has been significantly documented in the literature as being important for students to start at the right level to have success in college math (Ohland et. al., 2004; Moses et. al., 2011; Jin et. al., 2011; Middleton et. al., 2015). This idea was reinforced in these interviews, in addition to providing evidence that students do not mind if this throws off their math progression for degree attainment.

Students overall felt that they had positive formal academic integration experiences in Calculus I through the content they learned and their academic performance. However, the level of formal integration into engineering is more challenging to determine from the interview responses. The ideas found in the Institutional/College Factors theme challenges the ideas of the connection of Calculus I to engineering. Almost all of the students agreed that Calculus I did not connect them to the engineering community, but most of the students were satisfied with the curriculum as is. They felt the curriculum prepared them for the following math courses which is valuable academic integration in the math courses, but the evidence from the interviews does not fully support formal academic integration into engineering from Calculus I.

5.2.2 Informal Academic Integration into Engineering

It is important to note that informal academic integration primarily centered around the student's specific instructor for their Calculus I course or the student's academic advisor, so these people varied amongst all participants. The students were not asked about the names of their instructors or advisors but it can be assumed that most of the students had different Calculus I teachers based on the variety of math instructors that are assigned to that course and had different advisors based on their major at the time. As a result, there are some trends that students commented on about the experiences they had with their instructor or advisor that provided evidence to create suggestions of useful teaching and advising practices for these students as described in Chapter 6.

The primary interactions that students had with their advisors during the semester they took Calculus I included standard advising for course registration. A few students did mention that they received helpful resources for Calculus I from their advisors when they discussed having trouble in the course. These resources included the advisors providing different sources of help like the tutoring centers or other staff that could help out or showing the student the different registration options they have depending on their outcome of Calculus I. The students that received this information found it very helpful, but many students did not think to talk to their advisor about Calculus I. Students commented that they felt their advisor would not know about what they were experiencing or learning in Calculus I. Further, the fact that Calculus I was through a separate department from engineering also made it difficult to ask the advisors about the instructors. This may be a misconception on the students' behalf, but there was a lack in open communication between the students and their advisors on academic progress in these courses (apart from the final grade). This is a major area within the student-advisor interaction that could help students by providing an intervention earlier with these struggling students if the student is aware that they can discuss course happenings with their advisor. This could also be an opportunity for the advisor to follow up with the student prior to completely disengaging from the program and leaving engineering.

Most of the interviewed students mentioned that they had an instructor with a teaching style that allowed them to learn the material, apart from one persister and one leaver. These styles all varied for each student but included conceptual teaching, guided handouts, easy to understand explanations, being approachable, and straightforward with expectations. Since most of the students commented on the instructor style this factor is a major impactor on their overall experience in Calculus I. The positive experiences were memorable and each of these students mentioned their instructor style as a reason they had success in the course. The impact that instructors have on students is significant and should be considered for every course assignment (Spring and Schonberg, 2001).

There was one definite difference between persisters and leavers for informal academic integration. The leavers all mentioned that they had an instructor that was confusing or negative. This seems to contradict the previous comment that most students thought their instructor facilitated learning, but the leavers mentioned these comments as either relevant to their first Calculus I instructor or they did not feel comfortable approaching the instructor one on one. There was one student that commented that the instructor appeared to belittle the students, which is a personal opinion but affected their ability to learn from or interact with that person. This is the only theme that had a significant difference between persisters and leavers validating that developing informal academic integration with instructors is very important for students to integrate in the course and ultimately the engineering degree program.

Conversely, a common theme amongst informal academic integration was the lack of connection that students had with engineering faculty during Calculus I. Students did not know any engineering faculty or feel like they could approach engineering faculty. Since the students did not have an engineering course before or during Calculus I they did not have this type of connection to engineering. An engineering instructor could provide guidance or more personal experience about Calculus I and pursuing an engineering degree that students this early on are missing out on. This lack in informal academic integration could be another cause for students to not feel integrated into engineering and factor into their decision to leave the major. It is important to realize that this feeling was common for both persisters and leavers though, so it cannot be claimed as a reason that students leave engineering. It can be highlighted as a missed opportunity that if improved could provide these students with stronger connections and resources during this barrier course.

5.2.3 Do Students Academically Integrate into Engineering?

The results from the formal and informal academic themes appear to have a mixed message about integration. It has been stated that students feel they formally integrate into Calculus I which allows them to successfully continue on in their math and allows them to eventually end up in engineering courses, but Calculus I does not provide a formal academic integration directly linked to engineering. The material covered in the course has not connected to engineering enough to allow the students to see these connections and feel as though they are starting to develop engineering skills during that course. The informal academic integration results are similar in that students felt they could learn from their course instructor and be successful in the course, yet there was a lack of support from the advising and engineering instructors during this time to help students understand the importance of Calculus I for engineering. Further, it was found that the most significant difference from persisters and leavers was found in informal academic integration through negative experiences with a Calculus I instructor. This difference should be considered as a factor that can cause students to leave engineering. From the student responses, it is clear there is a lack of academic integration into engineering from Calculus I, both from the course content and faculty/staff interactions. This is a concern for engineering schools since it is a likely explanation for why students are leaving the major following this course.

5.3 Social Integration and Calculus I

The second research question for the qualitative strand of this analysis was:

2. How does an engineering student's social integration develop during Calculus I?

To answer this research question, several interview questions were created that focused on social integration in Calculus I and two social integration a priori codes were used in analyzing the interview data. The overall responses for both formal and informal social integration did not differ between persisters and leavers.

5.3.1 Formal Social Integration into Engineering

The formal social integration results show that there was a major lack in information about student clubs and organizations in engineering for students at this stage in their career. Without this information, students do not have a way to start connecting with student groups and organizations which have been shown to help integrate students into their degree program (Tovar, 2013). It is not surprising that students do not know about these types of student activities while in Calculus I since that course is offered outside of the College of Engineering and most students did not have an actual engineering course during that semester. Conversely, the four students that were involved in a non-engineering student group all valued the experience for the social involvement they had with it.

5.3.1 Informal Social Integration into Engineering

The results for informal social integration overwhelmingly pointed out that students did not feel connected to engineering students inside their Calculus I course and outside the course during that semester. The responses from the students describe the lack of opportunity to meet other engineering students during that semester. While both persisters and leavers formed study groups in Calculus I, this was not with the intention of connecting with engineering students and it was always facilitated by the students. The students described the study groups as one of the major reasons they had success in the course, but they did not feel like those groups helped to connect them to engineering students.

The informal social integration that the students felt Calculus I provided them was the ability to begin to recognize engineering students from their course. Students began making connections from the faces they saw in their Calculus I course to faces they would see in the hallways of the engineering buildings, so they started to be able to identify other students that were in a similar position as them. The interviewed students did not feel comfortable interacting with these students more than recognizing them, so there were never formal introductions made. Further, the students only recognized other students from their Calculus I or other science and general courses they had during their semester of Calculus I, which meant there was no connection to engineering students that were ahead of them in their degree program, not even facial recognition. Upper classmen could provide students with valuable support and guidance to students while in these initial math courses, but there was no encouragement for students to engage with one another.

Another interesting result was the lack in social integration that the students felt who had a recitation as part of their Calculus I course. The use of smaller recitations sections has been documented to provide benefits for students both academically and socially (Saad, Abu-Lebdeh, Pai, & Waters, 2007; Vasquez, Fuentes, & Freeman, 2012). However, the students that had a recitation did not mention any more social interaction or connection with students than those that had a lecture only course. This is likely due to the nature of the recitation or how the students participated in their section. The recitations could provide one of the best informal social integration opportunities if the environment is created for those types of connections. If students are given the opportunity to interact and move around during a recitation session while working on problems, then there is possibility of meeting other students with similar interests or struggles. This could be a valuable way for students to start meeting and forming study groups with other engineering students.

The lack of social integration is a known problem in engineering and many programs have made changes to help students with this. The creation of the freshmen engineering design experience at many schools was with the intent to introduce design to these students but social skills also develop. At the university where this study took place, there have been changes to the engineering degree program requirements that have helped students socially interact more. These changes have been added over the past several years and include the addition of an introduction course, a programming course, or a 1-credit connections course offered during their first semester. These courses benefit the students by grouping the same major students into a single course during their first semester in college, often at the same semester as Calculus I, but the social interaction amongst the students in these courses is still unknown.

5.3.3 Do Students Socially Integrate into Engineering?

The results show that there was hardly any evidence for the development of a student’s social integration into engineering during Calculus I. Students felt as though the course was separate from engineering and there were many students from other majors in it, so it was hard to feel connected to the engineering program during that time. There were not many social activities that the students were aware of inside or outside the classroom either. Students were also hesitant to try to connect with other students at this time and were not connected with students in their same majors. Calculus I did not help students socially integrate in engineering, and without that piece it is not surprising that many students leave engineering shortly following the course.

5.4 The Difference Between Persisters and Leavers

The final research question is

3. In what ways does social and academic integration differ for engineering persisters and leavers?

Ultimately, answering this question is trying to provide an answer as to how to prevent students from leaving engineering following their experience in Calculus I. The summary of the findings from the quantitative and qualitative analysis have shown the differences and similarities in the experiences the two groups of students have had. The end result of answering this question will be to provide recommendations that can help students integrate better during their time Calculus I.

For academic integration, the results show that there was a difference between the groups in both formal and informal academic integration. The interview results for formal academic integration did not have a major difference between the two groups, but the quantitative results provided evidence that there is a significant grade difference between the groups. This grade difference between persisting students and leaving students is significant, as represented in Tables 7-9 (p. 76, 78, and 79 respectively) and Figure 11 (p. 76). There was also one major difference found between the groups for the theme informal academic integration, which was having a negative or confusing interaction with a Calculus I instructor. The persisting students did not share any type of negative interaction with their instructors, but the leaving students all mentioned at least one instance of a bad interaction during Calculus I. These results show that the development of academic integration for persisting students and leaving students is different, where the persisters have positive experiences both formally and informally that allow them to integrate into that course and thus engineering.

The results for social integration did not differ amongst the two groups. Students from both groups reported a lack of formal and informal social integration into engineering while in Calculus I. This is a concerning result for both groups. Tinto's model has been applied and shown that students need both academic and social integration to feel connected to an institution, so the lack of social integration so early on for engineering students is a major reason for the low retention rate in the major.

These results offer evidence that persisting students academically integrate while in Calculus I, but the leavers do not and neither group develops social integration. As Tinto stated with his model, "Some degree of social and intellectual integration and therefore membership in academic and social communities must exist as a condition for continued persistence" (Tinto, 1993, p. 120). Through Calculus I only some students are developing academic integration and it is clear that none of them gain social integration, so for the students that lack both forms of integration at this point in their career that is likely one of the major reasons they are leaving the major. There are, of course, all the personal reasons that students experience that factor in, but this analysis did not show a major difference in these reasons between the two groups. The results show that persisters start to develop academic integration while leavers do not, and neither group develops social integration. Since it is important to have both forms of integration in one's major in order to decide to persist, it is the lack of both types of integration that the leavers experience as the reason they depart from the major so early on in their academic career.

The leavers may have a disadvantage academically, through course performance or their instructor, but without any social integration into engineering they cannot find a reason to stay. It is likely that if these students were developing social integration into engineering during Calculus I then they would be more likely to continue on in the major even with the initial poor academic experience. This social integration could provide them a support system for engineering that they do not currently have. On the other hand, if there was a way to intervene sooner with students that are performing poorly in Calculus I and help them be successful academically then it is likely that those students would also persist as a result of that. This would be a route to provide them academic integration that they currently do not feel they receive.

In the case of the persisters, while they did not experience social integration into engineering during Calculus I, they did start to experience positive academic integration. As a result, they are still in engineering and have learned to value the knowledge and experiences gained from Calculus I now that they can connect it to engineering. This indicates that students do not need both forms of integration initially, but need some form of assimilation into the engineering community. These students missed out on social integration during Calculus I, but the persisters expressed that they developed it in the following semesters with their engineering peers. They did begin to develop their academic integration and that was enough to provide them a reason to remain in engineering. The leavers did not experience either form, which is a major lack of connection that these students feel to engineering and as a result they have all switched their major.

5.4.1 Do Persisters and Leavers Integrate Differently into Engineering?

There is a difference in the integrative experiences persisters and leavers have in Calculus I. The table below summarizes these differences. The bold "**X**" represents integration for that group and the "-" represents no integration for that group.

Table 16

Differences Between Engineering Persisters and Leavers

Positive	Persisters	Leavers
Formal Academic Integration	**X**	- (poor grades)
Informal Academic Integration	**X**	- (negative interaction with instructor)
Formal Social Integration	-	-
Informal Social Integration	-	-

The leavers did not experience either social or academic integration, where the persisters had some form of academic integration. This study provides evidence that students do not need to fully integrate into the two systems at the start of engineering, but integration in at least one of the two systems is required to prevent the student from deciding to leave. The addition of opportunities and support that students do not currently have can help these students develop socially or academically into engineering during their time in Calculus I. The final chapter will provide recommendations on these types of opportunities as gathered from the literature, talking with the students, and from synthesizing the results.

CHAPTER 6

CONCLUSIONS

This study took a mixed method approach at understanding the academic and social experiences that engineering students have during Calculus I. The purpose of this study was to verify the low retention rate in engineering following Calculus I, along with showing how academic performance, formal and informal academic experiences, and formal and informal social experiences contribute to persistence in engineering. The results from the statistical analysis provide evidence of the influence that a student's Calculus I grade has on engineering persistence. The results from the student interviews identified that there is no form of social integration into engineering during Calculus I, and the leavers also did not develop academic integration during that course. The combination of the results from both methods offer a potential explanation for why students are leaving engineering following Calculus I. The students need to develop some form of integration into engineering from the start of their college career, it could be academic integration or social integration, but without at least one of these then the students are likely to leave. The results of this study indicate that students who have persisted in engineering have experienced academic integration through good academic performance and positive informal academic experiences without any social integrative experiences. The academic integration has been enough to retain them. The leavers had the opposite academic integration experience. Further, these results have highlighted the gaps in the Calculus I experience that can be addressed at various levels.

6.1 Recommendations

The low retention rate for engineers through the calculus series is not a new phenomenon and many universities have already created or changed programs to try to help the problem. This section will highlight some of these programs along with specific ideas that were developed from interviewing the students. The results from this study may be transferable to other engineering programs, and the recommendations will offer different routes to begin to adjust the student experience while in Calculus I.

6.1.1 Recommendations for Academic Integration

There were many factors that influenced academic integration in Calculus I like academic performance, course content, the instructor, and advising. Academic performance was one of the most significant factors for persistence, and one of the largest gaps students have was knowledge about math resources that could help them. These resources can include the different tutoring spaces or tutoring options, online help, or other math resources. The dissemination of this information could be done by the advising staff. Students did not feel like their advisors were a valuable resource to discuss Calculus I with, but if the advisors could voluntarily offer the students all these resources prior to starting Calculus I then they will have opened the line of communication for the course along with ensuring the student knows their options for help. Further, better tracking of at-risk students during the semester they are in Calculus I would allow advisors to intervene with the students earlier to get help. By helping students be more successful in Calculus I they are likely to continue on to the next course with confidence.

The course content of Calculus I was not a major concern of the students, but students could benefit from providing opportunities to integrate this course with engineering earlier on. There have been several schools that are an example of this (Venable et. al., 1995; Pines et. al., 2002; Willcox and Bounova, 2004; Dunn, Loch, and Scott, 2018). One recommendation that would be valuable not only for formal academic integration but also provide social integration to the students is to shift Calculus I to a corequisite course with the first engineering course. This was done at Clemson University with positive results for student retention (Ohland et. al., 2004). The reality is the prerequisite requirement of Calculus I does not make sense when students cannot connect the material from it to their engineering course. Also, the social integration benefit of requiring students to take an engineering course much earlier with their peers would be significant to their sense of belonging in the engineering community.

The instructors have been extremely variable for Calculus I, but the placement of the best instructors in that course will have a major impact on retention. The students that felt like the instructor had a good teaching style, or they could engage or interact with their instructor were ultimately more successful. Calculus I is often assigned to whoever can fill the spot or even teaching assistants, but this is a disservice to the students especially this early in their career. The assignment of instructors that want to invest in helping students engage into their course and integrate into the program would make a significant difference in the student experience. Also, the use of active learning as part of the instructor's teaching style can facilitate social interaction as well which can help increase that part of the system.

6.1.2 Recommendations for Social Integration

As the students expressed a desire for social interaction with the engineering community earlier on, the opportunities for social integration have the most potential and were lacking in all areas. The first recommendation would be for engineering student organizations and groups to target the freshmen students much more than they have. Currently, students in Calculus I are not aware of many of the opportunities to get involved with engineering students through extracurricular activities. The use of email to try to notify students of these opportunities does not work either. At a minimum there needs to be representatives from each different club attend the Calculus I sections or other general courses that are predominately freshmen engineering students to try to recruit these students. This would give these new engineering students a face to connect with and ensure that they have heard about all these opportunities and resources first hand. By getting students involved with these engineering activities earlier, they can build up their social network and start to develop a social investment in engineering. This social network is also likely to help the students academically because it will provide insight into these courses through the older students that have already been through those early courses.

Finding ways to have students interact more on an informal social integration level is more challenging because that is individually driven. However, the use of more in class activities and engagement with other students would benefit this. Allowing the students to connect more in class will carry over to outside the classroom. The use of recitations is to provide these opportunities, but even the recitation sections need to be set up to be more interactive and engaging for students to really value working with one another and develop a connection. Also, the creation of other courses for freshmen engineering students will further this opportunity. There are some freshman engineering courses that have been created both at this university and other universities (Corleto, Kimball, Alan, and Maclauchlan, 1996). However, the reason some of these courses do not significantly add to a student's social integration is because they are created with a very rigorous academic agenda in mind. For example, courses like *Introduction to Programming*, which is required of all electrical and computer engineering students as their first engineering course, has a curriculum geared towards learning a skill leaving no time for student interaction during the course. If the use of these courses shifted slightly to be about student connection with their peers while achieving the same academic goal, then they will provide better social networking for the students early on. Further, if these courses can be grouped by math level, as was done at West Virginia University, then this will provide social and academic benefits for them in math (Venable et. al., 1995).

6.1.3 Recommendations for the College and Institution

The final emergent theme of Institutional/College Factors was unexpected, but demonstrates the influence that college level decisions have on the development of each student. Many of the interviewed students expressed interest in having a Calculus I section only for engineering students. This course could still be offered through the math department with a registration restriction for declared engineering majors only. Additionally, placing this course in a classroom in the engineering building will provide students with a connection from Calculus I to engineering. This would not change the current organization of how Calculus I is set up at the research university, but would provide better social and academic integration opportunities through the location of it and the student population in the course.

Another change that could have significant academic benefits would be to require a common curriculum for all calculus courses. The students that took multiple Calculus I sections did not see the same material in both classes, and the students also felt like the expectations in Calculus II did not always align with what was learned in Calculus I. By having a more consistent curriculum amongst all courses, the students will have a better chance to be successful in this series. This would also be useful to ensure that all of the Calculus I instructors are providing the most useful and relevant information to every student in the course. There is a variety of people assigned as the instructors of Calculus I and the other calculus courses that it would be desirable to have a standardized curriculum.

There is also a need for math specific tutors in the engineering tutoring center. These could be upper class engineering students who have been successful in the math courses. Many of the participants in this project would visit the math tutoring center for help in their courses and were not aware of the engineering tutoring center until after the course. If there are tutors available in the engineering tutoring center for the math courses, then these students will be able to seek help amongst their engineering peers. This would cause them to utilize some of the provided engineering services along with connect to other engineering students who have been through the math courses and some of the engineering courses and have firsthand experience with both.

The final recommendation is for the design of the engineering degree program. The placement of Calculus I in these degrees has been a common source of critique (et. al., 2004; Pembridge and Beach, 2013). By modifying the requirement of Calculus I from 1st year, 1st semester for engineering students to stay on track to the 2nd semester of that year the students will be more ready, both academically and socially, for the course. A student's first semester in college is a huge transition emotionally, socially, intellectually, and personally, and funneling students right into Calculus I does not provide a lot of positive experiences for them to develop these things. The shift of just a single semester would help the students better integrate and absorb the material of the course.

6.2 Conclusions and Future Work

This study has provided evidence for the lack of academic and social integration from Calculus I for engineering students. These constructs are extremely important for these students to develop or else they are likely to leave before they get into the core engineering courses. The lack of social integration that students experience in Calculus I is a major problem, but there are a variety of ways to mitigate this including offering the students more opportunities to engage with each other and student organizations during this early phase of their schooling. The difference in the academic experiences of persisters and leavers is also concerning but there are routes to provide all students with similar academic experiences with the potential of retaining more students. This would require changes from the instructors, advisors, and even the College of Engineering, but those changes have the potential to impact the 50% attrition rate in engineering.

This analysis did yield meaningful results; however, the data was limited. One of the most significant ways to expand on this research is to collect more data from this institution for other math and early engineering courses and then to expand to other institutions. Since all data came from a single institution that has a unique student population there would be value in expanding the data set to other universities in order to provide generalizability of the results. This could also include interviewing students at a university that has already modified how Calculus I is offered to their engineering students. This will provide a contrast to the social and academic integration results found from the Calculus I offering at the research university.

A second area for additional research would be to expand the results to Calculus II and Calculus III. This expansion would allow for a better understanding of how students develop social and academic integration long term and in different courses. This study only provides a snapshot of this development in a single course, but Tinto's model is longitudinal, so adding an increase in the time dimension would add to the understanding of these systems throughout engineering.

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APPENDICES

Appendix A

IRB Letter of Approval

UtahState University
OFFICE OF RESEARCH AND GRADUATE STUDIES

Institutional Review Board
USU Assurance: FWA#00003308

Exemption #2

Certificate of Exemption

Full Accreditation

FROM:

Melanie Domenech Rodriguez, IRB Chair

Nicole Vouvalis, IRB Administrator

To:	Virgil Adams, Amie Baisley
Date:	December 12, 2018
Protocol #:	9905
Title:	The Influences Of Calculus I On Engineering Student Persistence

The Institutional Review Board has determined that the above-referenced study is exempt from review under federal guidelines 45 CFR Part 46.101(b) category #2:

> Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (a) information obtained is recorded in such a manner that human subjects can be identified, directly or through the identifiers linked to the subjects: and (b) any disclosure of human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

This exemption is valid for three years from the date of this correspondence, after which the study will be closed. If the research will extend beyond three years, it is your responsibility as the Principal Investigator to notify the IRB before the study's expiration date and submit a new application to continue the research. Research activities that continue beyond the expiration date without new certification of exempt status will be in violation of those federal guidelines which permit the exempt status.

As part of the IRB's quality assurance procedures, this research may be randomly selected for continuing review during the three year period of exemption. If so, you will receive a request for completion of a Protocol Status Report during the month of the anniversary date of this certification.

In all cases, it is your responsibility to notify the IRB prior to making any changes to the study by submitting an Amendment/Modification request. This will document whether or not the study still meets the requirements for exempt status under federal regulations.

Upon receipt of this memo, you may begin your research. If you have questions, please call the IRB office at (435) 797-1821 or email to irb@usu.edu.

The IRB wishes you success with your research.

Appendix B

Recruitment Email

Dear Student,

I am a Ph.D. candidate working with Dr. V. Dean Adams in the department of Engineering Education in the College of Engineering at Utah State University (USU). I intend to study undergraduate students that have taken Calculus I (Math 1210) at USU as a declared engineering or computer science major for my dissertation. You are invited to participate in this study due to your registration in Calculus I during Spring 2017 or Fall 2017 at USU.

Purpose: My goal is to understand the influence that Calculus I has on an engineering students' academic and social integration in the engineering degree program. This will uncover the issues and misconceptions that students have about the engineering program from this course and how that impacts their decision to persist in or leave the degree program.

Compensation: For your participation in this study, you will receive a $25 gift card shortly after completing the interview process.

Eligibility Criteria: To be eligible for this study, you must meet the following conditions:

- Registered in Calculus I (Math 1210) during Spring or Fall 2017 as a declared engineering or computer science major
  ** Both students that are still declared engineering or computer science majors and students that have since switched their major are invited to participate

The Study: If you agree to participate, you will be asked questions about your experience in Calculus I, both socially and academically, and about your perception of the engineering community. If selected to participate in this study, you will be required to attend the following:

- **Orientation session** (5-10 min)
- **Interview session** (15-30 min)
- **Voluntary follow-up results session** (OPTIONAL and can be done through email; 30 min)

If you would like to participate, ***click on the link below*** to complete an online Qualtrics survey, which contains questions about eligibility criteria and asks you to provide an email address I can contact you at.

Qualtrics Survey Link: https://usu.co1.qualtrics.com/jfe/form/SV_8k8PjAcOoyHftT7

If during your participation in the study, you become concerned about potential conflicts of interest, please communicate with the Principal Investigator of this study, Dr. V. Dean Adams, who will assist you in determining any pertinent steps as needed. He may be reached at 435-797-9114 or dean.adams@usu.edu. If you would like to speak with someone other than the researchers about questions or concerns, please contact the IRB Director at (435) 797-0567 or irb@usu.edu.

Thank you.

Appendix C

Pre-Interview Survey

1. What was your declared major when you took Calculus I?
2. What is your current major?
3. Select when you took Calculus I during your college career.
   a. 1st year, 1st semester
   b. 1st year, 2nd semester
   c. 2nd year, 1st semester
   d. 2nd year, 2nd semester
   e. other (please describe year and semester)
4. If you are interested in participating in this study, leave an email address that the research can contact you at.

Appendix D

Orientation Session Email

Hello!

Thank you for filling out the Qualtrics survey and expressing interest in the study. If you would still like to participate in the study, I would like to set up a time to meet with you for an orientation session. In this session I will explain the study and your involvement in further detail, answer any questions you may have, and set up a time for the interview. I will also have a letter of consent for you to sign. I have attached a copy of the letter of consent to this email, but I will go over the letter in detail during the orientation session.

Please let me know what times and dates would work for your schedule. The orientation session should only last 15-30 minutes. Also, let me know if you have any questions at this time.

Thank you.

Appendix E

Semi-structured interview protocol

Start of Interview:

[*Interviewer greets the participant and starts a friendly conversation.*]

Interviewer: Thank you for agreeing to participate in this study, and as a reminder, participating in this interview is voluntary and you can choose to withdraw from participating at any time. If you have any questions or need clarification of a question, please let me know. You can choose to skip any question you do not want to answer. Is it okay to audio-record this interview?

Did you read through the letter of consent? Do you have any questions about it?

Do you have any other questions before we begin the interview?

Experience questions:

1. Describe a positive experience you had in Calculus I?
2. Describe a negative experience you had in Calculus I?
3. Was there anything that could have improved your experience in Calculus I?
4. How prepared were you to take Calculus I?
5. How did Calculus I prepare you for your following courses?
6. What helped you/could have helped you succeed in Calculus I?

Social integration questions:

7. In what ways did you feel connected to the other students in your Calculus I course?
8. Did you connect with other engineering students outside of your Calculus I course?
9. Were you involved with an engineering student club or student organization during the semester you took Calculus I?
    a. What opportunities were available?
    b. What was your role?
    c. Was there anything that prevented you from getting involved?

Academic integration questions:

10. What was your comfort level in going to talk to your Calculus I instructor?

11. What was your attitude about going to talk to an engineering instructor or academic advisor during the semester you took Calculus I?
12. Did you go talk to an engineering instructor or academic advisor during the semester you took Calculus I?
    a. What was your experience like?

Community questions:

13. Can you define what the engineering community is to you here at Utah State University?
14. While in Calculus I, did you feel connected to the engineering community at Utah State University? Please explain.
15. How did Calculus I influence your level of connection to the engineering community?

End of the Interview

I have stopped recording. Do you have any questions about the interview?

That is the end of the interview. Thank you for your time.

Appendix F

Codebook

6 major themes:
Formal academic integration
Informal academic integration
Formal social integration
Informal social integration
Personal reasons
Institutional/College reasons

*Each theme can include both positive and negative experiences for that particular theme.

Name of Code	Formal academic integration	Informal academic integration
Description	This code includes any mention of academic performance in Calculus I, preparation for Calculus I or other courses, and mention of the course content. This could include the grade received, how the student felt they learned the material, how the content was taught, applied, or related to other courses.	This code includes any mention of interaction with faculty or staff inside and outside the classroom relative to the course. The faculty could include the course instructor or other supportive engineering instructors. The staff could include advisors, tutors, and other college staff.
Inclusion Criteria	Any mention of performance in a course or ability to grasp the material. Also, any statement that references previous knowledge, concept application, sense making of a concept/topic, learning of a new concept/topic.	Any interaction during class, before/after class, office hours, appointments, or other types of meetups. Any mention of the instructors teaching style. Also, any visits to tutoring centers or other type of formal education help (e.g. not informal student study groups). This can include interaction with faculty or advisors that is not specific to Calculus I.
Exclusion Criteria	Mention of other course factors not related to the content or performance including the overall experience in the course or stating course facts such as the time in which the course was taken. Any interaction with faculty or students in the course should not be included.	Informal student study sessions. Mention of other factors in the course such as content, experience, and learning environment.
Typical exemplars	“Taking it the second time around I can see how the concepts of calculus are applied to engineering and physics…” “I didn’t have to take any remedial stuff before I took calculus…” “I took 1050 and 1060 the previous semester which helped”	“Both teachers were graduate students…” “He taught it more conceptually…” “I went to the math tutoring center at night…” “I think he did a really good job of teaching us…” “I liked my recitation leader would give us a

	"A decent grade in the class" "More trigonometry review would be helpful…"	short overview…" "Advising is harder with math classes because they don't know the professors…"
Atypical exemplars	"There was really no grade incentive to do the homework" "I remember doing my homework right after class" "It got me on the path to have similar understanding of how to work on problems…" "I already know what was going on in the class…" "Helped me structure my workload better…" "More examples of engineering and how it applies…" "Did not prepare me for Calc II…"	"Get more one on one time with the physics instructors…" "I didn't feel the need to go talk to them about calculus I…" "I don't even know if I had an engineering instructor then…" "I've learned in two years that office hours are really crucial…"
"Close, but no"	"It was my first time in calculus…" "My instructor was able to help me on reviewing trig…"	"The instructor had us form study groups…"

Name of Code	Formal social integration	Informal social integration
Description	This code includes any mention of getting involved (or not) with extracurricular activities, student clubs, or student organizations.	This code includes any mention of working with other students, meeting other students, connecting with or getting help from other students inside or outside of the classroom.
Inclusion Criteria	Any mention of getting involved or doing an activity with organized student clubs during the semester of Calculus I. Includes clubs relative to engineering or other clubs and student organizations through the university.	Any mention of meeting, working or studying with other students or getting help from other students outside of the classroom. This code also includes the mention of interacting with the people inside the class, any social classroom experience, and the class dynamic.
Exclusion Criteria	Meeting up with a student group about course material or other courses is not extracurricular. An extracurricular activity not associated with the university.	Mention of friends that are not relative to Calculus I or engineering. Friend groups that do not involve the student's major, course, or success at the university should not be considered.
Typical exemplars	"I was doing a lot of stuff with other clubs that were not engineering…" "I was in a club that was predominately engineering majors…" "I was on the swing dance team…"	"I had a study group, so me and a couple other students in the class would work together…" "We were able to just study together every day…"

		"I could go to one of my friends with a question…"
Atypical exemplars	"I could join a club but it costs money…" "I was aware of a few, but not all that was probably offered…" "I was aware that there's like clubs…" "The problem was they were just at bad times, the clubs would meet in the evenings…"	"Everyone kept to themselves in class and I felt like I was the only one…" "We had a common goal and it was nice to have somebody who was like yes it was very hard…" "Even though we might be a little bit awkward, if you put forth the effort we're pretty nice people…" "I've taken more classes with the same people…" "I didn't feel like I was up to par with a lot of other engineering students…"
"Close, but no"	"I would meet up with friends to play Frisbee…"	"Class of probably 30 or 40 students in recitation…"

Name of Code	Personal Reasons	Institutional/College Reasons
Description	This code includes any personal reasons that helped a student persist or have difficulties during Calculus I.	This code includes the way the course was set up, any logistics about the time/place of the class, and the placement of the course relative to the other engineering courses in the degree.
Inclusion Criteria	Any mention of external support, self-efficacy, desire to be an engineer, injury, interest in the subject or other personal reason. The personal issue must be from the individual themselves from outside the university to help them have success or failure in Calculus I.	Any mention of not connecting to engineering or the other engineering courses, the time or room of the course, or lack of communication amongst calculus sections. Includes the way the course was set up as either lecture or lecture with a recitation and class size.
Exclusion Criteria	Support from anyone affiliated with the university or help from university sources. Any comments about the material in the course or the way the course was taught.	Mention of anything specific to the instructor or their teaching style.
Typical exemplars	"I knew engineering was really hard and that's why I wanted to do it…" "It's really prestigious…" "Before my concussion I was good at math…"	"It was only lecture…" "It was at nighttime so our focus was off…" "The information we got from the two different professors were different…" "Very few connections were made to the engineering college…"
Atypical exemplars	"Just another class to get through…" "Engineers are hardworking, committed	"I went on to calc II and some of the stuff the professors were expecting me to know I

	and innovative…"	didn't know…" "The basement didn't have any windows so that was kind of depressing…" "I was like this isn't what I expected in engineering…" "At least brought me back into the engineering building…"
"Close, but no"	"I could not understand the concepts from the course…"	"I found a good friend in calc II but not in calc I…"

Amie Baisley

CURRICULUM VITAE

EDUCATION

August 2019 Ph.D. Engineering Education, Utah State University
Dissertation Title: *The Influences of Calculus I on Engineering Student Persistence*
Dissertation Advisor: V. Dean Adams

May 2013 M.S. Structural Engineering, Arizona State University
Thesis Title: *Multiphysics Design Optimization Model for Structural Walls Incorporating Phase Change Materials*
Thesis Advisors: Subramaniam Rajan and Narayanan Neithalath

Dec. 2011 B.S. Civil Engineering, Arizona State University

TEACHING INTERESTS

- Undergraduate engineering courses: Statics, Dynamics, and Solid Mechanics
- Structural Analysis
- Introduction to MATLAB
- Educational Theories and Research Methods

RESEARCH INTERESTS

- Engineering student persistence particularly during the first two years
- Impacts of the math courses on engineering students
- Linking engineering education research to the engineering classroom
- Alternative pedagogies in the classroom including student-centered, engaged environments
- Alternative assessment strategies incorporating mastery-based assessment and self-assessment

TEACHING EXPERIENCE

2013-2015 Lecturer, Department of Civil and Environmental Engineering, Arizona State University

- Courses taught over 5 semesters: Statics, Dynamics, Solid Mechanics, and Introduction to ASU
- Flipped each course to a problem-based learning environment
- Assessed students for mastery on a core set of subject specific objectives
- Abandoned the textbook and developed all materials for each course including course notes, examples, recitation problems, computer projects, assessment questions, and rubrics
- Class sizes ranged from 60-120 students depending on the semester
-

2012-2013 Teaching Assistant for Dynamics, Department of Civil and Environmental Engineering, Arizona State University

RESEARCH EXPERIENCE

2016-present Research Assistant, Department of Engineering Education, Utah State University

- Develop analysis programs to process student/instructor data from the math courses for the College of Engineering

2011-2013 Research Assistant, Department of Civil and Environment Engineering, Arizona State University

- Developed a time-dependent finite element analysis program

PUBLICATIONS

A. Stockwell [Baisley], N. Neithalath, and S.D. Rajan. Multiphysics Design Optimization Model for Structural Walls Incorporating Phase Change Materials. *Engineering Optimization*, *47 (3), 308-327, doi: 10.1080/0305215X.2014.887706,* (2014).

GRANTS, FELLOWSHIPS, AND AWARDS

2013 Outstanding Research Poster, Multiphysics Design Optimization Model for Structural Walls Incorporating Phase Change Materials
2012 JumpStart Research Grant, Arizona State University, Amount: $500
2011 Reach for the Stars Fellowship, Arizona State University, Amount: $15,000

SERVICE

2016-2019 Webmaster USU-American Society for Engineering Education
2015 Curriculum Committee, Department of Civil and Environmental Engineering, Arizona State University
2015 ASU-American Society of Civil Engineers Faculty Mentor
2011-2012 Secretary ASU-American Society of Civil Engineers

PROFESSIONAL MEMBERSHIPS

American Society for Engineering Education (ASEE)
American Society of Civil Engineers (ASCE)
Order of the Engineer
Chi Epsilon

WORK EXPERIENCE

2011-2013 Arizona Department of Transportation, Intern for Traffic Engineering and Bridge Engineering Divisions