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The Effects of Mathematics Placement on Successful Completion of an Engineering Degree and how One Student Beat the Odds

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The Effects of Mathematics Placement on Successful Completion of an Engineering Degree and How One Student Beat the Odds

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Abstract

This dissertation comprises a sequential explanatory mixed methods study seeking to understand persistence in engineering based on a student's initial mathematics course and the experience of a student who began in the lowest level mathematics course and completed an engineering degree despite struggling in mathematics courses.

The first phase of the quantitative piece examines one year retention rates for first year engineering students based on initial mathematics course. In the second quantitative phase a stepwise logistic regression model was conducted to determine what factors are related to engineering persistence. The third quantitative phase is a retrospective study to determine the initial mathematics course for graduating engineering students. The final phase of the quantitative piece examines graduation rates for first year engineering students based on initial mathematics course.

Results of the first phase indicate engineering students starting in non-college level mathematics courses are significantly less likely to be retained in engineering a year after their first semester compared to students starting in one of the calculus courses. In the logistic regression model with initial math course, grade in the initial math course, gender and race as predictor variables, course, grade, and gender were found to significantly predict retention in engineering one year later. Results from the third phase indicate very few students graduating with an engineering degree start in precalculus. It also shows some engineering disciplines may be more attainable for students starting in non-college level mathematics courses, like precalculus. Results of graduation rates in the fourth quantitative phase confirm engineering students starting in precalculus are significantly less likely to graduate with an engineering degree than those starting in any higher level mathematics course.

A case study was conducted to fully explain how a student persisted in engineering after starting in precalculus. One of the few students starting in precalculus who graduated with an engineering degree was interviewed to understand why he chose engineering, why he didn't quit or change majors when he had to repeat calculus II multiple times, and how he was able to complete his calculus courses despite his mathematical deficiencies. Other individuals who he indicated were influential in his success were also interviewed. A framework combining future time perspective and self-regulation was used to explain his experience and why he didn't quit. Another framework on self-regulated learning strategies was used to explain how he was able to successfully complete calculus II.

The case study student's dream of becoming a pilot in the Air Force and his 'can't quit' attitude were the motivation for his persistence in engineering. An instructor in the Mathematical Sciences Department and the instructor's ability to model self-regulation strategies were instrumental in the student's eventual completion of an engineering degree. By understanding the experience of one of the few successful engineering students who started in a non-college level mathematics course, educators can better advise future students with similarly poor mathematics backgrounds.

Dedication

This work is dedicated to my family. Without all of you, this would not have been possible.

To my parents, thank you both for your love and support during this process. Mom, thank you for rearranging your work schedule to help watch the girls while I complete my degree. To my Dad, I was wrong, I got that bored! Thank you for your constant encouragement and last-minute assistance with editing.

To my grandparents, thank you for being the best babysitters!

To my sister, thank you for your encouragement along the way.

A special thanks to my husband and kids. Jason, thank you for sacrificing your career in order to be at home with the girls during the day while I advance my career. I will be forever grateful. And to our daughters, Katelyn and Michaela, you two are my sunshine. I wear a lot of hats, but my mom hat is the one I am most proud of and the one I most enjoy wearing.

I love you all very much!

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I would like to thank the Department of Mathematical Sciences for allowing me to pursue this degree while maintaining my position in the department. Thank you to my current and former department chairs, Drs. Chris Cox, Jim Coykendall, and Bob Taylor, for supporting this endeavor. Thank you to Dr. Judith McKnew for being my editor and for all of your encouragement. Thank you Connie for your help and friendship.

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And most importantly, I thank God for giving me the opportunity and ability to complete this degree and for blessing me with family and friends without whose love and support none of this would have been possible.

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Chapter 1

Introduction

The aim of this study is to determine persistence and graduation rates for engineering students based on their initial mathematics course and to gather and analyze detailed evidence to explain the experience of one student who completed an engineering degree despite struggling in mathematics. This research was first inspired by research at another university where they found that the grade in an engineering student's initial mathematics course correlated with persistence in engineering, but the course level did not.[3] They also found that retention for students starting in calculus was not significantly different than those starting in lower level courses. It was hypothesized that this was not the case at our university and I sought to examine if results would support that hypothesis. In chapter 2, a conceptual replication study is conducted. The results of this study lead to the overarching research question.

If an engineering student starting in calculus is more likely to graduate with an engineering degree than one starting in precalculus, how does a student complete an engineering degree program after struggling through

mathematics courses?

To fully answer the research question, the following subquestions will also be answered:

1. What are the graduation rates for engineering students with different initial mathematics courses?
2. In what ways did the student struggle?
3. How did the student get through the required mathematics courses?
4. Why didn't the student give up or change majors when he was required to retake required courses multiple times?

To determine if a student 'struggled' in mathematics, their transcript was analyzed. Students who had poor grades (D, F, withdrawals) in mathematics or mathematics related courses, but mostly As and Bs in their other courses were identified as ones who likely struggled in math. In other words, they were able to achieve academic success in their other courses, but had trouble completing the required mathematics courses. Students who made As and Bs (maybe a few Cs) in all of their courses were not put in the 'struggled' group, nor were the students who had poor grades in most of their courses. While those students may have had a difficult time in math courses, they also may have had other extenuating circumstances and/or did not devote as much time to their studies as they should have.

To meet my research aims, I followed a sequential explanatory mixed methods design,[4,5] in which a quantitative part is followed by a qualitative part that explains some phenomenon found in the quantitative results.[5,6] The quantitative part (Chapters 2 and 3) will examine academic records for first year students who declared engineering as their intended major to find how many graduated in engineering within six years, answering the first half of the mixed methods research question and the first subquestion. The qualitative part (Chapter 4) consists of a case study on one successful student who started in precalculus and completed an engineering degree program. Data for the case study includes academic transcript information, test grades for mathematics courses, an open-ended survey, and interviews with both the participant and those the participant identified as influential in his success and determination to persist in engineering. Results from the case study will fully describe the difficulties the student faced in mathematics, how he was able to overcome those obstacles, and why he didn't quit.

The results of this dissertation will inform the way in which we advise new freshmen wanting to major in engineering, but who are required to start in precalculus. Study strategies that effected student success in calculus courses have been identified, and the role that setting subgoals plays in achieving a future goal has been emphasized. Helping students successfully complete required mathematics courses that they find challenging will help retention in engineering as a whole. Studying the experience of one of the few successful students can inform others and hopefully increase the engineering retention rate which will help address the national need for more STEM (science, technology, engineering, and mathematics) graduates.

Note: This work was approved by Clemson University's Institutional Review Board, number 2013-201. All data collected, statements of informed consent, survey, and interview protocols were approved through the IRB. To provide anonymity and maintain confidentiality, the names of all participants have been changed and only two members of the research team are aware of their true identity.

Chapter 2

Persistence in Engineering: Does Initial Mathematics Course Matter?

This paper was presented at the 2015 American Society for Engineering Education Annual Conference and Exposition in Seattle, WA and appears in the conference proceedings: Paper ID #12104.

To include in this dissertation, the following modifications were made 1) double-spacing, 2) references to figures and tables were modified to indicate new numbers (ex: table 1 became table 2.1), 3) Chi-square test statistics and odds ratio estimates were added to Table 2.2, and 4) all references were combined with the rest of the dissertation and listed at the end of the document.

Van Dyken, J., Benson, L. & Gerard, P. Persistence in Engineering: Does Initial

Mathematics Course Matter? *ASEE Annual Conference and Exposition* (2015).

2.1 Abstract

This study is situated within a larger project that seeks to understand how students that start in precalculus and struggle in their math courses persist and complete an engineering degree program. The specific aims of this study are to determine 1) the extent to which students that start in precalculus persist in engineering after one year, 2) correlations between the grade in engineering students' first math course and/or the level of that course and persistence in engineering one year later, and 3) the relative number of students that graduated with an engineering degree who started in a non-college level (pass/fail) mathematics course.

Data were collected and analyzed from academic records for all first semester engineering students at a southern land grant university, including the mathematics course for which the students were registered that semester, their grade in that course, and their major at the end of the following fall semester. The results of the analysis showed that both the level and grade in students' first college mathematics course are significant predictors of retention in engineering: students starting out in a non-college level mathematics course and those making a D, F, or withdrawing from their first mathematics course are less likely to still be in an engineering program a year later than those that begin in a calculus course or those that made a C or better in their first mathematics course.

Additionally, our results showed that fewer than 12% of graduating engineers during a single semester at our institution started in a non-college level mathematics course.

In contrast, nearly 40% of graduating engineering students entered the university with AP or dual enrollment credit for single variable calculus.

This quantitative study of trajectories of students who start out in non-college level mathematics was conducted to identify the subject(s) for a future qualitative study of the factors that contribute to students' persistence in engineering when they encounter difficulties in their college mathematics courses.

2.2 Introduction

At our institution, historical data shows that students who declare an engineering major and begin in precalculus as freshmen are unlikely to complete an engineering program. Most of these students will either leave the university or change majors, and will not complete their initial goal. For example, over a three year period, from 2003 to 2005, 141 engineering students at our university were in precalculus in the fall semesters, but only 68 of them were still in an engineering major just one year later. That is a retention rate of just over 46%. Of the 68 retained, 44 of them (67.69%; 31.2% of the original population of engineering students taking precalculus as their first mathematics course) finished precalculus with a passing grade. Based on this historical data, we hypothesized that both the final grade and course level for a student's first mathematics course at the university are significant in predicting retention in engineering.

Prior research at another land grant institution showed that the grade a student earns in his or her first college level mathematics course was highly significant in predicting persistence in engineering, while the mathematics course level they began in was not.[3] These researchers also found that retention for students starting in calculus was not statistically different from those that started in precalculus. Our study was inspired by this research to explore these trends at our institution. There is value in replicating studies, especially if done by independent researchers.[7] While this isn't an exact replication, we felt it was important to determine if results would be similar at our institution.

2.3 Research Methods

To meet our research aims, we conducted two quantitative studies. The first study examined academic records for first year students that declared engineering as their intended major to find how many persisted in engineering one year later and what factors significantly predicted persistence. The second study examined at what level students that graduated with an engineering degree began in their mathematics sequence.

Study One: Retention in Engineering One Year Later

For this study, to see what percentage of students were retained one year after starting at our university based on their first mathematics course, we collected data for all first year engineering students in Fall 2010 ($n = 865$). Transfer students and continuing students were not included in this study. The data were collected from the university's student information system and included their major in Fall 2010, the mathematics course they took that semester, their final grade in that course, gender, race, and declared major one year later. Students were considered retained if their major was still in an engineering discipline at the end of their third semester (one year after they completed their first semester at the university). Data were matched and collected using Panorama (a hybrid database/spreadsheet application), and then retention percentages were computed in Excel.

We chose to use data from the Fall 2010 cohort as it served the additional purpose of a retrospective study (see Study Two below) of the levels at which students graduating with engineering degrees began their mathematics course sequence. To confirm our findings from 2010, we expanded Study One to include the same data for all new freshman engineering students in Fall 2009, 2011, and 2012. We ran a chi-square test using the statistical software JMP to test if retention was the same from year to year for each course. Chi-square tests are appropriate when comparing proportions and testing for independence. Because retention was not found to be statistically different ($\alpha = 0.05$), we combined data for all four years to create a larger data set ($n = 4040$).

At our university, all incoming students take the Clemson Math Placement Test (CMPT). For the population of students in our study, the CMPT was offered online and consisted of 25 algebra and 25 precalculus questions. Students were required to take the test before registering for their first mathematics course. Based on their scores and AP/transfer credits, freshmen engineering majors were placed in either precalculus, long calculus, calculus I, calculus II or calculus III. For students seeking an engineering degree at our institution, precalculus is the lowest level math course in which they can begin. It is a five hour pass/fail course with no prerequisites. Students scoring slightly higher on the CMPT but not high enough to be placed in calculus have the option to begin in “long calculus”. Long calculus is a two semester sequence course, where the first semester is a four hour pass/fail course that spends approximately a third of the semester reviewing precalculus material. Calculus I material is introduced, and almost twice as much time is spent on each topic than in regular calculus I. The second semester is a four hour graded course that continues the calculus I material. Students passing both semesters of long calculus are given credit for calculus I. Students scoring high enough on the CMPT can be placed in calculus I. However, students may only start in calculus II or III if they have AP/transfer credit for the prerequisite course. Calculus I – III are all four hour graded courses. Precalculus and the first semester of long calculus are considered non-college level courses, because they are pass/fail and cannot satisfy a general education mathematics requirement.

To identify what factors are predictive of a student persisting in engineering, we used the statistical program SAS to run a stepwise logistic regression, with race, gender, grade in first mathematics course, and course level as potential predictor variables. While our other tests were run in JMP, we specifically chose SAS for the regression model as it does stepwise regression. We felt this was the best way to determine which variables should be left in the model. The default significance levels (0.05) for entry and stay were used.

Study Two: Where Graduating Engineers Began Mathematically

We wanted to determine the level at which the students began at our university in their mathematics courses. In our second study, we collected data for students that graduated in Spring 2014 with a degree in an engineering discipline ($n = 432$). We only included students that began as freshmen at our university, so no transfer students were included in our study. Our data included students' majors, as well as the level of the first mathematics courses they enrolled in at our institution. Given that relatively few students transfer into engineering from other non-STEM (science, technology, engineering, and mathematics) majors,[8,9] we only included students that started in one of our mathematics courses required for STEM majors (those discussed in Study One).

To increase the size of our cohort, we collected the same data for graduating engineers in Spring 2013. We ran Fisher's exact tests to compare the enrollments in each course and found that there was not a statistical difference in course enrollment percentages for the two different years, allowing us to combine them to create a larger data set ($n = 814$).

2.4 Results

Study One: Retention in Engineering One Year Later

Table 2.1 includes retention rates in engineering for students starting in different mathematics courses (combined Fall 2009 – 2012 data). These were found to be statistically different based on results from the chi-square test. The percentage of engineering students starting in non-college level mathematics courses (precalculus and long calculus) is lower than those starting in one of the calculus courses (I – III). Also, the percentage of students leaving engineering is much higher in those same courses than those starting in calculus. In fact, nearly half of the students starting in precalculus, and almost 40% of those starting in long calculus, left their intended majors within the first year.

In the logistic regression model with grade, course, gender and race as predictor variables, and retention after one year as the response variable, grade and course were

Table 2.1: Retention of students in engineering one year after starting by initial course

Course	Enrollment	Retained in Engineering	Percent Retained
Precalculus	123	65	52.85
Long Calculus	574	362	63.07
Calculus I	1667	1311	78.64
Calculus II	681	581	85.32
Calculus III	995	896	90.05
Total	**4040**	**3215**	**79.58**

found significant, as well as gender, at the 0.05 significance level, and were retained in the model. This means that both grade and course significantly predict retention in engineering one year later, which supported our hypothesis and confirmed our earlier findings that students starting in the lower level courses were less likely to stay in engineering. Also, students earning lower grades in their first mathematics courses were less likely to stay in engineering majors, supporting findings from other studies.[3,10] Table 2.2 gives the estimates for the final model, which explains the log odds of students starting in any one course or a specific grade persisting in engineering compared to a reference level, while the other variables are kept constant. Log odds are determined by calculating $e^{Estimate}$. For example, for students starting in precalculus (Course – Precalculus), by computing $e^{-2.0265} = 0.132$, we find that the odds of a precalculus student being retained in engineering one year later is 13.2% of the odds for a student starting in calculus III (the reference level for course). In terms of gender, we found that women were less likely to be retained in engineering than men, with odds for a female persisting in engineering a year after her initial mathematics course was 73% of the odds for a male. Of the 4,040 students in our study, 3595 (89%) are white, which may be why race did not prove to be significant in our model.

Table 2.3 shows retention in engineering based on grade received in first mathematics course for the four years combined. Not surprisingly, students that did well in their

Table 2.2: Logistic regression model for students persisting in engineering one year after beginning based on grade, course and gender. Each predictor variable has one degree of freedom ($df = 1$). Reference levels: Calculus III, Grade of W (withdrawal), and Male

Predictor Variables	**Estimate**	**Standard Error**	**Chi-Square**	**Odds Ratio Estimate**
Intercept	1.34	0.18	55.11	–
Course – Precalculus	-2.03	0.27	54.76	0.13
Course – Long Calculus	-1.60	0.21	55.54	0.20
Course – Calculus I	-1.05	0.13	69.91	0.35
Course – Calculus II	-0.40	0.15	6.84	0.67
Grade – A	1.49	0.19	60.75	4.44
Grade – B	1.32	0.19	48.18	3.73
Grade – C	0.70	0.20	12.64	2.01
Grade – D	0.39	0.25	2.55	1.48
Grade – F	0.12	0.21	0.35	1.13
Grade – P	1.27	0.25	24.87	3.55
Gender – Female	-0.31	0.10	10.34	0.73

mathematics classes were more likely to stay in their engineering major. However, it is surprising that only 70% of those who received a grade of 'P' were retained. This means that 30% of students who successfully completed the non-college level course decided to change majors or leave the university. The percentage of these students is only slightly lower than the students that withdrew from the course that semester (33%).

Study Two: Where Graduating Engineers Began Mathematically

Figure 2.1 shows the percentage of students starting in a specific mathematics course that graduated with an engineering degree from our institution in Spring 2013 or 2014.

There are very few students graduating with an engineering degree that begin in our non-college level mathematics courses (precalculus or long calculus). The majority

Table 2.3: Retention of students in engineering one year after starting by grade in initial mathematics course

Grade	**Retained**	**Not Retained**	**Total**	**Percent Retained**
A	1022	133	1155	88.48
B	936	149	1085	86.27
C	442	118	560	78.93
D	121	42	163	74.23
F	240	183	423	56.74
P	326	138	464	70.26
W	128	62	190	67.37
Total	**3215**	**825**	**4040**	**79.58**

of students graduating with a degree in engineering started in one of the calculus courses. Many of those students entered the university with AP credits and were able to start in calculus II or III. The relatively high number of students that entered with AP credits and chose engineering as their major agrees with the finding that students taking AP calculus in high school (whether or not they completed the AP exam), are more likely to choose a STEM major in college over the other disciplines, with engineering being just as popular as mathematics and the sciences combined.[11]

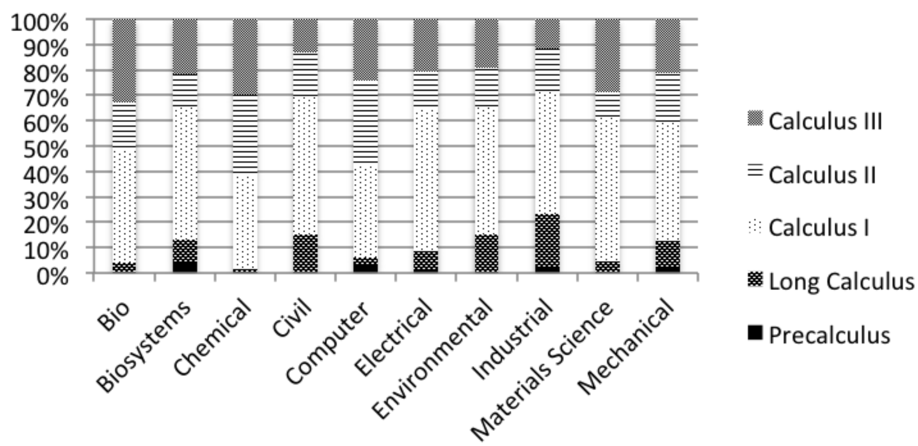

Figure 2.1: Percentage of students starting in different mathematics courses who graduated in Spring 2013 or 2014 by Major

2.5 Discussion

Based on four years of data, we have shown that the percentage of students retained in engineering one year later is significantly lower for those that begin in non-college level mathematics. Nearly 50% of those starting in precalculus, and nearly 40% of those starting in long calculus, either change majors or leave the university, compared to 21%, 15%, and 10% that begin in calculus I, II and III respectively. These values are at the same level as attrition rates for engineering majors over an entire college career, which are reported to be between 40 and 50 percent.[8,10,12,13]

At our university, students are not eligible to take introductory engineering courses if they start in precalculus. This adds another obstacle for students that are already starting behind in mathematics. Burtner found that a student's confidence in their college level mathematics ability significantly predicted persistence in engineering.[14] If students are getting the message that their mathematics skills are too weak to take an engineering course in their first semester, many of them may choose to leave engineering within their first year.

By running a logistic regression model on the four year data set, we showed that not only does the grade earned in a student's first mathematics course significantly predict retention in engineering one year later, but so does the level of that first math course, as well as gender. While gender isn't the focus of this study, it is well known that women are not well-represented in engineering disciplines;[8,9,13,15] identifying ways to increase the level of their first mathematics course as well as their performance in that class may help to address this disparity.

In our second study, we showed that very few students that graduate with engineering degrees start in a non-college level mathematics courses. However, based on our data it did appear that there were certain engineering majors that could be more attainable than others for those students, specifically biosystems, civil, environmental, industrial, and mechanical engineering. While our first study showed that almost half of the students starting in the lower level courses leave the major (or university) within the first year, our second study showed a pattern that suggests that very few of those that were still in engineering a year later would successfully complete an engineering degree. It is widely understood that mathematics knowledge, skills and ability (KSA) are important to being successful in engineering education;[9,16–18] students who are lacking mathematics KSA are starting out at a deficit in non-college mathematics courses before they even begin their intended engineering courses.

One limitation of this study is that precalculus and long calculus are pass/fail courses, whereas calculus I – III are letter grade courses. When we used grade as a predictor in the regression model, we kept the pass/fail courses as P's and F's, and the other courses as letter grades. It is possible that if they were on the same scale, the results may have been different. However, to test this on a subpopulation in our cohort, for Fall 2010 we were able to obtain final numeric grades for students in precalculus and long calculus, which we converted to A, B, C, D, or F. When the regression model was run for just Fall 2010 data using letter grades for all courses, both grade and course level were still significant in predicting retention in engineering one year later. Because we did not have access to numerical grades for all courses, it was not possible to compare average grades for each level of mathematics course. Thus we could not determine if, for example, students in higher level courses earn higher grades, or if grades are evenly distributed across all levels. At institutions that record numeric grades, this would be an interesting area for future studies.

Another limitation of this study is that we did not include grade point average (GPA) in our analysis. Our population is incoming students, and as such they do not have a GPA when they start their mathematics course sequence. However, GPA after their first year in their engineering programs may have an effect on whether or not they choose to stay in engineering. Future versions of our logistic regression model should include GPA one year later as a possible factor in retention in engineering.

As stated earlier, the research for this paper was inspired by research done at another institution.[3] One of the differences between their institution and ours, is that they offer non-credit bearing mathematics courses. Students that aren't ready for precalculus would take one of their developmental algebra courses as a prerequisite. Our university does not offer such courses. Differences in course offerings could explain why our results did not match those at the other institution, and why they may be different for other institutions. If a student is not ready for precalculus and the university does not have a lower level course for them to take, this could affect retention. Another difference between our courses and theirs is that our non-college level mathematics courses are graded pass/fail, while the students in their lower level courses, including precalculus, appear to be given letter grades. It is possible students treat a course differently depending on how the course is being graded. If a student feels there is less pressure in a pass/fail course, they may not put as much effort into it, and thus may find themselves failing after it is too late to catch up, or they may only do enough to pass, not fully grasp the material, and then find themselves struggling in their subsequent mathematics courses. Both of these scenarios would affect retention.

2.6 Conclusions and Future Work

It is clear based on our research that students starting in non-college level mathematics are significantly less likely to graduate with their intended engineering degree than those that begin in a calculus course. To improve retention in engineering, further qualitative studies are needed to understand what barriers may exist for the students who aren't able to make it through engineering programs. The focus of this study is not on identifying ways to improve retention in engineering; however we seek to inform practice through results from this and future studies. We also need to understand factors that contribute to students' success in completing engineering degrees for those who start in non-college level mathematics. To that end, we will be conducting a case study of one or more of the six students that began in precalculus as engineering majors in Fall 2010 and are close to successfully completing engineering degrees. We will do interviews with these students and others that they identify as being influential in their success in completing their degree program. We will examine details about the curricula, other programs or resources that may have contributed to their success. Results from this case study will provide information that will benefit future students wanting to major in engineering, but who lack the mathematical background needed to start in a college level mathematics course. Additional work is underway in our research group that incorporates effects of self-efficacy and grit on students' persistence in engineering when faced with struggles in mathematics courses.

Chapter 3

Engineering Graduation Rates Based on Initial Mathematics Course

3.1 Abstract

Retention in engineering for students who begin in precalculus is significantly lower than for those who start in calculus I. Almost half of the precalculus students leave the university or change majors within a year of their first semester. In this quantitative study, six year graduation rates and majors for first year engineering students are determined based on their initial mathematics course. Results show an engineering student starting in calculus I is more than three times more likely to graduate with an engineering degree than an engineering student starting in precalculus. Results also confirm earlier findings that certain engineering disciplines may be more attainable

for students starting in precalculus than other engineering disciplines. This study was conducted to reiterate the impact mathematical deficiencies have on success in an engineering program, but also to identify the participant for a case study on one of the few students who began in precalculus, but persisted and graduated with a degree in industrial engineering.

3.2 Introduction

Several large scale studies ($n \geq 30,000$) have found the six year graduation rate for engineering students to be around 50%.[10,19,20] Calculus I and II have been identified as barrier courses for engineering students, along with physics and statics.[21] These are courses in which students typically struggle and have high withdrawal and failure rates. Some refer to them as 'weed out' courses.[13] Many students struggle with the concepts and skills necessary to be successful in the course. This is especially true of students who come in with deficiencies and are required to start in non-college level mathematics courses. These students have lower SAT scores and poor study habits compared to students who 'sail' through calculus.[21] The initial mathematics course an engineering major takes has been found to be related to persistence in engineering.[22,23] Students starting in a math course lower than calculus I are less likely to persist in engineering. We hypothesized that the attrition rate for precalculus students would increase over time as they work through the curriculum and attempt the required "barrier" courses. By looking at graduation rates and major at graduation, we will be able to inform advisors, faculty, and future students on the likelihood of graduating with an engineering degree depending on initial mathematics course, and which disciplines students might be more successful in if they start out in precalculus.

3.3 Research Questions

This quantitative study will answer the subquestion, *What are the graduation rates for engineering students with different initial mathematics courses?* This corresponds with the first half of the overarching mixed methods research question: *If an engineering student starting in calculus is more likely to graduate with an engineering degree than one starting in precalculus, how does a student complete an engineering degree program after struggling through mathematics courses?*

3.4 Methods

3.4.1 Participant Selection and Data Collection

The population for this study is students who enter the university committed to majoring in engineering. All data was collected from students at Clemson University. Clemson University is a tier-one, land grant institute in the south, with a strong military heritage. The university has roughly 17,000 undergraduate students and over 80 majors. Data were collected for all new students who matriculated in the fall between 2006 and 2010 and who indicated engineering as their major of choice. As nearly all new students matriculate during the fall semester of an academic year, data were only collected for the fall semester. Continuing students were not included in this study, nor were students who began in the summer or spring. The data were collected from the university's student information system and included their first semester major, the mathematics course they took their first semester, their graduation term and graduating major.

The Clemson Mathematics Placement Test (CMPT) is an online test required of all new students. For the years collected, the CMPT consisted of 50 questions, 25 from algebra alone. Depending on their CMPT score and any advanced placement or transfer credit, new engineering majors at our university begin in either precalculus, long calculus, calculus I, II or III. Long calculus is a two semester course that begins with a review of algebra and trigonometry before moving on to the calculus material. Both precalculus and the first semester of long calculus are considered non-college level and are graded on a pass/fail scale.

A binary variable was created indicating if a student graduated within six years. Using six years to measure graduation rates is common practice in education research.[20,22,24–26] This allows for deficiencies to be addressed, students to participate in co-ops, internships, or study abroad experiences, as well as the completion of any extra degree requirements their major may have. Another binary variable was created indicating whether a student graduated in an engineering discipline. For the years the data were collected there were ten engineering majors at our university: biomedical, biosystems, chemical, civil, computer, electrical, environmental, industrial, materials science, and mechanical. Environmental engineering was a new major. A student from the Fall 2007 cohort was the first to graduate in environmental engineering.

3.4.2 Data Analysis

After the data were pulled from the university's information system, they were matched by student ID numbers using Panorama (a hybrid database/spreadsheet application). Graduation rates were calculated in Excel. Using the statistical software JMP, chi-square tests were run to determine if the six year graduation rates were significantly different over the five years for each initial math course. Because the graduation rates were not found to be significantly different at the $\alpha = 0.05$ level (see test results in table 3.1), the data were combined for all five years to create a larger data set ($n = 3896$).

Table 3.1: Independence test results for graduation rates over years (2006 - 2010) for each initial math course

Course	**Chi-Square**	**P-value**
Precalculus	2.65	0.63
Long Calculus	6.81	0.15
Calculus I	2.57	0.63
Calculus II	1.19	0.88
Calculus III	7.53	0.10

With the combined data set, an overall chi-square test was run to determine if the six year graduation rates were statistically different between the initial mathematics courses. Pairwise chi-square tests were then run to compare graduation rates between courses.

3.5 Results

Table 3.2 gives the number of engineering students matriculating between Fall 2006 and Fall 2010 based on their initial mathematics course, the number who graduated, and the number who graduated in engineering. The last column gives the percent of engineering students who graduated in an engineering discipline.

Table 3.2: Six year graduation rates of students in engineering by initial math course

Course	**Enrollment**	**Graduated**	**Graduated in Engineering**	**Percent Graduated in Engineering**
Precalculus	173	84	33	19.08
Long Calculus	695	482	281	40.43
Calculus I	1772	1460	1159	65.41
Calculus II	619	506	424	68.50
Calculus III	637	560	500	78.49
Total	**3896**	**3092**	**2397**	**61.52**

The proportions of students who initially declare engineering as their intended major and successfully complete the degree program is also represented graphically in Figure 3.1. As can be seen, more than 80% of students starting in precalculus either change majors, leave the university, or are unable to complete the program within six years, compared to less than 40% in each of the calculus courses.

The graduation rates were found to be significantly different for the five initial mathematics courses based on the chi-square test (p-value < 0.001). The percentage of students starting in precalculus who graduate within six years is significantly lower than those starting in long calculus or one of the calculus courses (I - III). In fact, to answer the quantitative part of the mixed methods research question, an engineering

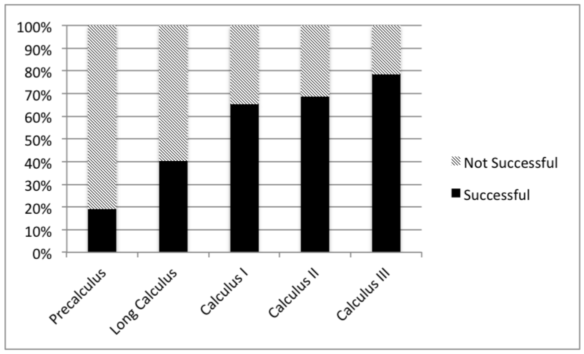

Figure 3.1: Six year graduation and attrition rates for engineering majors ("successful" indicates the percentage of undergraduate engineering students who started in that particular initial mathematics course and successfully completed an engineering degree program within six years, "not successful" indicates the percentage of undergraduate engineering students who started in that particular initial mathematics course and either left the university, changed majors, or didn't complete the degree within six years)

student starting in calculus is almost 3.5 ($65.41/19.08 = 3.43$) times more likely to graduate with an engineering degree than one starting in precalculus.

The results from the pairwise chi-square tests can be seen in Table 3.3. Only graduation rates for students starting in calculus I and those starting in calculus II were not significantly different.

Table 3.3: Pairwise chi-square test comparing graduation rates between courses

Course 1	**Course 2**	**P-value**
Precalculus	Long Calculus	< 0.0001
Precalculus	Calculus I	< 0.0001
Precalculus	Calculus II	< 0.0001
Precalculus	Calculus III	< 0.0001
Long Calculus	Calculus I	< 0.0001
Long Calculus	Calculus II	< 0.0001
Long Calculus	Calculus III	< 0.0001
Calculus I	Calculus II	0.1600
Calculus I	Calculus III	< 0.0001
Calculus II	Calculus III	< 0.0001

Figure 3.2 shows the percentage of students starting in a specific mathematics course between Fall 2006 and Fall 2010 who graduated in each of the engineering disciplines. The overall distribution is included at the end as a baseline. From this graph we can see the majority of graduating engineers began in one of the calculus sequence courses. There are engineering disciplines with higher than average percentages of students starting in precalculus, like electrical, environmental, and industrial. Along with these three disciplines, biosystems and civil have a higher than average percentage of students starting in long calculus. This confirms what was seen in Chapter 2, that biosystems, civil, environmental, and industrial engineering have the highest percentage of graduating engineering students who started in non-college level mathematics (precalculus or long calculus).

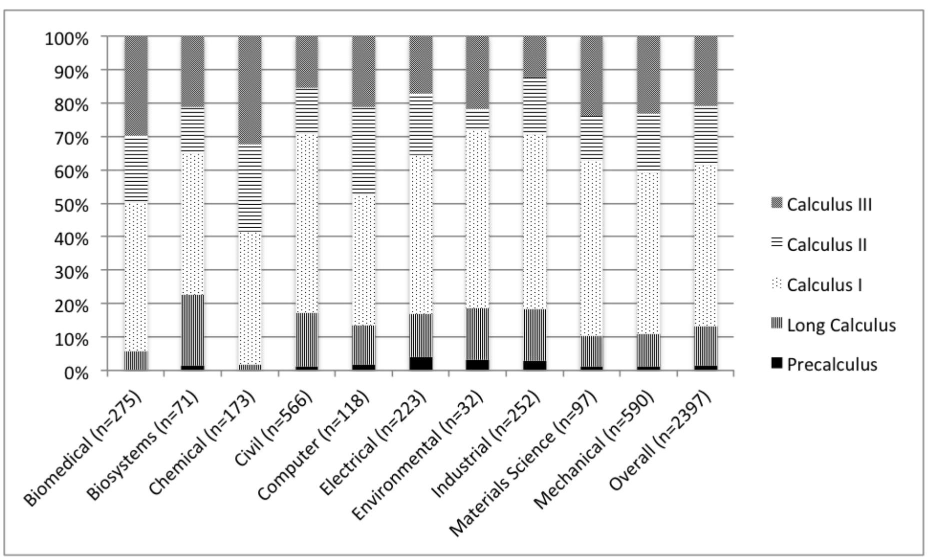

Figure 3.2: Percentage of engineering graduates starting in different mathematics courses by major

3.6 Discussion

Based on five years of data, we have shown the percentage of engineering students graduating with an engineering degree within six years is significantly lower for those who begin in precalculus. While the overall graduation rate (61.52%) is in line with other research,[10,13,19,20,24] the graduation rate for those starting in precalculus (19.08%) is extremely low. More than 80% of students starting in precalculus who want to major in engineering, compared to 35% of those starting in calculus I, either leave the university, change majors to something outside of an engineering discipline, or are unable to complete the degree in a timely manner.

Levin and Wyckoff found a student's algebra placement test contributed the most in predicting an undergraduate student's persistence in engineering.[27] The students scoring poorly on the CMPT and placed into precalculus are those with poor algebra skills. Students who have a difficult time with mathematics and have to start in non-college level mathematics courses are more likely to drop out.[28,29] At our university, these students not only enter the university with mathematical deficiencies, but by starting in precalculus, they are unable to take the introductory engineering, physics, or chemistry courses. They are not just starting behind in math, they are starting an entire semester behind their peers. This in turn affects the extent to which they are part of an engineering program.

In the previous chapter, it was shown that the one year retention rate for students starting in precalculus is just above 50%. But with a graduation rate of less than 20%, it is clear that just because they can make it through precalculus, that doesn't mean they can make it through an engineering curriculum. These students who begin with mathematical deficiencies must also make it through three calculus courses. Universities recognize that calculus I and II are difficult courses for students, often referring to them as "barrier" courses.[21] Multiple types of support programs exist to help students successfully complete the calculus sequence and increase engineering retention rates, like integrating real world engineering problems into calculus II as extra credit,[30] offering a grade recovery option in calculus I, consisting of attending study sessions and doing extra assignments for students who failed their midterm,[28] creating learning communities for entering students,[24,31] implementing peer-led team learning,[32] and offering supplemental instruction for calculus courses.[33,34] Studies show students who took calculus in high school have statistically higher grades in calculus I and II in college,[35,36] which further outlines the disadvantage students beginning in precalculus are at.

From the data, it appears certain engineering majors could be more attainable for those students starting with mathematical deficiencies. Looking at all graduating engineering students, biosystems, environmental, and industrial engineering have higher percentages of those starting in a non-college level mathematics course. Electrical, environmental, and industrial have the highest percentage of graduating students starting in precalculus. However, because environmental was a new major, the sample size may not be large enough to make inferences. Ohland et. al. found industrial engineering to have the highest 'stickiness' when compared to biomedical, chemical, computer, electrical, and mechanical engineering.[37] That is, *number graduating in major* $\div$ *the number of students ever in that major* is higher for industrial engineering than any of the other engineering disciplines. In their study, 55% of students who ever declared industrial engineering as their major graduated with an industrial engineering major. Further research needs to be done to understand why industrial engineering is able to graduate so many of its enrolled students.

3.7 Conclusion

It is clear from this quantitative study that engineering students starting in precalculus are significantly less likely to graduate with an engineering degree than those who begin in a higher level mathematics course. With so few precalculus students completing an engineering degree program, it is important to look at and learn from the experience of successful students. Further qualitative research is needed to understand what challenges precalculus students encounter while trying to complete the required mathematics courses and what resources help them achieve academic success in engineering. The following chapter describes a case study of one of the few students who began in precalculus and graduated with an engineering degree. Through his story, we are able to identify possible resources and advice we can instill on future students coming in with similar mathematical deficiencies but who want to major in engineering.

Chapter 4

Precalculus as a Death Sentence for Engineering Majors: A Case Study of How One Student Survived

4.1 Abstract

Few students wanting to major in an engineering discipline who begin in precalculus actually make it through an undergraduate engineering degree program. Most leave the university or change majors. This research uses theoretical frameworks of future time perspective and self-regulated learning to explore one successful student's experience as he struggled through his mathematics courses, but was able to overcome those struggles and graduate with an engineering degree. By understanding why a

student with mathematical deficiencies chose to persist in engineering when many others starting in the same lower level math course chose to leave, we can help future students with a similarly poor mathematics foundation persist.

A case study was constructed around this student, using quantitative data from his mathematics and engineering courses, as well as qualitative data in the form of an open-ended survey and interviews. Three other individuals who were instrumental to the student's success were also interviewed. During analysis, an existing theoretical model was enhanced to fully outline the student's mathematics education experience and motivation to continue in engineering. In addition, a framework of self-regulated learning strategies was used to explain how the student was able to successfully complete calculus II despite taking the course four times.

The student's desire to become an Air Force pilot in the future and his 'can't quit' attitude were the driving forces in his decision to persist in engineering. A mathematics instructor was key to his success in passing the required courses in the calculus sequence, which were contingent steps on the path to completing his engineering degree. The results of this study will inform the way in which we advise new freshmen who wish to major in engineering, but who are required, because of deficiencies in their background, to start in a non-college level mathematics course. Understanding the experience of one of the few successful engineering graduates who started in a non-college level mathematics course at our university will lend insight into the effectiveness of various resources made available to students. If we know the strategies a student with a poor mathematics foundation uses while completing calculus, we can advise and educate other students with a similar background how to utilize the same strategies.

4.2 Introduction

Attrition in engineering has been a well documented problem, with $40 - 60\%$ of students who entered a university as an engineering major choosing later in their studies to change majors or to leave the university.[8,10,12,13,38] Calculus I and II are known barrier courses for engineering majors.[21] Performance in these barrier courses, as well as the interest and motivation to succeed in engineering, effect a student's persistence in an engineering program.[21,39] Mathematics ability in general has been identified as the best single predictor of success in engineering.[27] By understanding the difficulties students face in mathematics courses, methodologies to help students overcome those struggles and become more successful in their pursuit of engineering degrees can be identified.

At our university, historical data shows that students who declare an engineering major and begin in precalculus as freshmen are unlikely to complete an engineering degree program. Most of them will leave the university or change majors.[23] This research seeks to understand the factors that contribute to students' persistence in engineering when they began their studies in a pre-college level mathematics course and struggled with their mathematics courses. Many of the students who remain in the program repeat one or more mathematics courses. The fact that so few are able to succeed in an engineering program after starting in a pre-college mathematics course begs the question: What is it about those students who do make it, and what about their experience might be used to help future students stay on track?

4.3 Theoretical Frameworks

4.3.1 Future Time Perspective

Future time perspective (FTP) examines how students' future goals effect actions they take in the present and what, if any, subgoals or contingent steps they recognize as being necessary to get there.[40–42] With a contingent path, one cannot proceed to the next step without successfully completing the previous step.[41,43] For example, a student cannot take calculus II until successfully completing calculus I. Students with long-term goals better understand consequences of current class activities on their future goals. Because of this, they are able to plan ahead, create subgoals and find ways to make progress along their contingent path.[41,42,44] Perceived instrumentality is the extent to which one sees the current task as being important to reaching one's future goal.[1,41,42] Instrumentality is either endogenous if the task is central to their future goal, or exogenous if the task is seen as merely a requirement to move to the next task, having no other value for their future goal.[45] A student's perceptions of instrumentality of their course work to their future goals has been found to be positively correlated with self-regulation and persistence.[46] For students with required courses as 'steps' in their path to their future goals, failure in the course will require them to repeat the 'step', which increases the distance from their future goal.

Personally valued future goals are set by the student and commitment to them sets the stage for the development of proximal subgoals used to reach their future goal.[1,47] As the path of subgoals becomes more concrete and the student moves further along the path, the more committed they become to their future goal.[48] The higher their self-efficacy for accomplishing their future goal (the more they believe they can attain it), the more effort they'll put toward reaching it.[49] Once realistic proximal subgoals have been set, self-regulated learning in the form of self-observation, self-evaluation, and self-reaction play a role in completing these subgoals.[1,50,51]

4.3.2 Self-Regulated Learning

In 1986, many of the most influential researchers in the field of self-regulation, including Monique Boekaerts, Paul Pintrich, Dale Schunk, and Barry Zimmerman, attended a symposium of the American Educational Research Association and agreed self-regulated learning (SRL) was the degree to which students are 'metacognitively, motivationally, and behaviorally active participants in their own learning process'.[52,53] Pintrich later defined SRL as "an active, constructive process whereby learners set goals for their learning and attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their contextual features in the environment[54] (p.453)". Self-regulated students use cognitive learning strategies (rehearsal, elaboration, organization) and metacognitive strategies (planning, monitoring, regulating) to understand course material and complete tasks.[52,55–58] Self-regulated students also manage and control effort on tasks by managing their time, adjusting their study environment as necessary, and seeking assistance when needed.[52,55–59]

After interviewing 40 high achieving and 40 low achieving students using their self-developed Self-Regulated Learning Interview Scale, asking students what they would do to plan or complete an academic task, Zimmerman and Martinez-Pons developed a framework with 14 self-regulated learning categories: self-evaluation, organizing and transforming, goal-setting and planning, seeking information, keeping records and monitoring, environmental structuring, self-consequences, rehearsing and memorizing, seeking social assistance from peers, teachers or adults, and reviewing tests, notes or textbooks.[60] In their study, they found high achieving students used more self-regulation strategies than low achieving students. Many studies have shown the use of self-regulation strategies improves academic performance.[53,55,57,61,62] Self-regulated students seek out information and assistance when they need help.[63] Instructors can encourage students to ask for help by showing them the intrinsic value in learning and putting them in group situations where they can help peers.[64]

To self-regulate is a choice a student who is motivated to learn makes.[58,65,66] Zimmerman says, "Positive self-perceptions are assumed to be the motivational basis for self-regulation during learning."[60] Students who are interested in the material, believe it is important, and believe they are are capable of successfully completing the task are more likely to use learning strategies and be successful.[52,55,57,61,67] Tabachnick et al. discussed how students starting in remedial courses, such as precalculus, have typically weaker self-regulation strategies, such as study skills. It was shown in their study that goals, both future and proximal, predicted self-regulation strategies.[68] Students with poor or no self-regulation strategies have been defined as having maladaptive learning profiles.[69,70] Engineering students have been found to adopt these maladaptive learning profiles while taking required foundational courses outside of engineering, like calculus.[70] These students either didn't use any self-regulation strategies, were unsuccessful during self-regulation, or weren't engaged enough during self-regulation to retain knowledge.[69,70]

4.3.3 A Model Connecting FTP and SRL

Goal-setting, a common strategy during self-regulation, is the key link between future time perspective and self-regulation.[60,61] Miller and Brickman developed a model of future-oriented motivation and self-regulation (see Figure 4.1) that combines theories of future time perspective and self-regulated learning.[1] Their model proposes that one's future goals influence self-regulation in the present and encourage one to create proximal subgoals, which act as stepping stones on the path to their future goal. Once these subgoals are set, self-regulation is triggered to help set and accomplish tasks within each of the proximal subgoals. Those who see the tasks and proximal subgoals as being instrumental in reaching their future goals are able to see the value in completing the subgoals.[42] If they are able to connect their current tasks to future goals, they'll have more control over the future[41,44] There is personal satisfaction from knowing they completed the current task and are one step closer to reaching their future goal.

4.4 Research Questions

This case study will answer the following subquestions pertaining to the student's completion of required mathematics courses:

1. In what ways did the student struggle?
2. How did the student get through the required mathematics courses?
3. Why didn't the student give up or change majors when he was required to retake required courses multiple times?

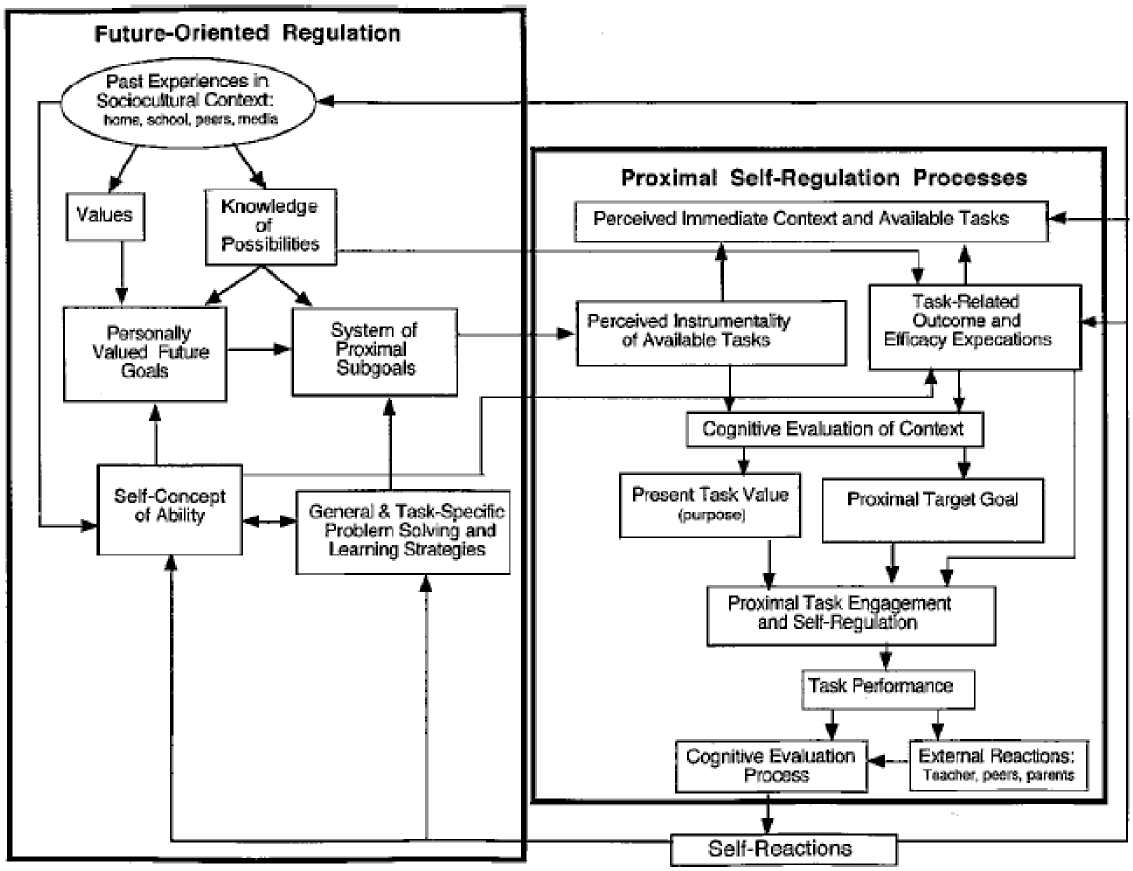

Figure 4.1: A model of future-oriented motivation and self-regulation. From "A model of future-oriented motivation and self-regulation," by R. B. Miller and S. J. Brickman, 2004, *Educational Psychology Review, 16,* p. 13, Figure 1. Copyright 2004 by Springer/Kluwer Academic Publishing. Reproduced with permission of Springer

4.5 Methods and Data Sources

4.5.1 Participant Selection

The population from which the case study participant was selected is students who enter the university committed to majoring in engineering, but who lack the mathematical background to begin in a college level mathematics course. One of the cohorts from the quantitative study in the previous chapter had thirty-one such students who began in precalculus, the lowest level mathematics course in which an engineering major can begin. Of those, only seven students were either able to complete the curriculum or were still progressing and on track to graduate within six years when our study began. This particular cohort was chosen because we wanted to be able to interview the participant(s) as close to their graduation date as possible, and all were within six years from university matriculation. It was concluded two of the seven did not struggle in mathematics based on their grades in subsequent mathematics courses (A's and B's) and the fact that they did not have to repeat any mathematics courses. They likely should not have been placed in precalculus in the first place and while they were included in the quantitative study, they were not considered for this case study, since we were looking specifically for students who had difficulties in mathematics. The case study student, "Nick", was selected out of the remaining five students because he was an exemplar who fit our criteria and responded to our email invitation to participate in the study. Nick started in precalculus with engineering as his declared major, struggled in his mathematics courses, having to repeat calculus II multiple times, but made it through an engineering curriculum and graduated with a degree in industrial engineering five years after matriculating.

4.5.2 Data Collection

Case studies serve to get at the depth of a phenomenon.[71–74] It is of interest to understand the experience of our case study participant in his mathematics courses, his difficulties in mathematics, and why he didn't give up or change majors. To fully answer the research questions about the student's experience, our case study is bounded by his engineering education experience, including any prior experiences that influenced or motivated him to major in engineering, his academic preparation prior to college, the advising he received while in college, and his experience during his mathematics-based courses.

To understand how and why our case study participant persisted in engineering while having to repeat calculus II several times, Nick was first asked to complete an open-ended survey based on engineering and math identity. The survey asked questions such as, "Do you see yourself as an engineer/math person?" and asked him to describe a time he was recognized as an engineer/mathematician. It also asked what he wanted to do for a career and who (or what) was most influential on his career choice. Many of the open-ended survey questions were adapted from a study which looked at women in engineering and their sense of belonging.[75] The survey was modified by removing the questions which focused on physics identity and adding questions which asked about mathematics courses taken at the university, which ones were difficult, why, and how challenges were overcome.

The results from the open-ended survey were used to create the interview protocol for the first interview with Nick. The goal was to further understand why he chose engineering as a major, why he didn't quit or change majors when he was having a hard time with math, and who helped him or encouraged him the most during his college experience. During his first interview, Nick identified his mother, one of his advisors, and an instructor in the Mathematical Sciences Department who served as a mentor over multiple semesters as being instrumental in his success and persistence in engineering. These three individuals were interviewed, which provided the opportunity to validate what Nick said in his interview[76] and strengthen the case study. These interviews were followed by a second interview with Nick to further clarify his mathematics background (high school), the consequences of starting in a non-college level mathematics course, and what the result would have been had he changed majors to something other than an engineering discipline. The survey was completed and all interviews were conducted during his final semester. The open-ended survey and interview protocols are given in Appendix A.

4.5.2.1 Researcher's Perspective

I am the main author and interviewer, and I am a lecturer in the Mathematical Sciences Department. I have a bachelor of arts degree in mathematics and a masters degree in mathematical sciences. I am conducting this research to complete my PhD in engineering and science education while continuing as a lecturer in the Mathematical Sciences Department. During my nine years of teaching I have taught many mathematics courses, including the long calculus sequence (a description of long calculus is in Chapter 3). Based on my experience and current position, I fully understand that the students in long calculus are there because they did not have a high enough score on the university's math placement test to start in calculus I. Many of the students have a difficult time with the review material. Typically, these students come in with poor algebra skills. Because I've taught this course multiple times and have seen many students with the same problem (poor mathematics preparation), when I selected Nick as my case study, I suspected Nick also came in with poor algebra skills, especially because he started in precalculus, an even lower level course than long calculus.

Within my job, I've seen the poor retention rates for engineering students starting in precalculus and long calculus. I've spoken with students who chose to leave engineering for a major requiring different math courses. Some say they leave because engineering wasn't what they thought it was. Others leave because they think engineering will be too difficult. Some have mentioned the math is too hard. With so few students staying in the program who start in precalculus and long calculus, it was important to me that I find out more about them. Why didn't they change majors too? Is there something we could have done to help motivate or better prepare the students that did give up?

I am also the registration coordinator for the Mathematical Sciences Department. As registration coordinator for the department, I have access to detailed information on a student's math placement test, test and daily grades for both calculus I and II, all transcript grades, and SAT and ACT scores. Upon selecting the case study participant, I realized from his transcript that he was in a section of the first year engineering course that was included in a separate study of engineering students' problem solving skills (NSF award number EEC - 1048325, "CU Thinking"). As a result, we have examples of his course work, as well as exam grades from that course. A subset of this quantitative data (math placement test information, transcript grades, and first year engineering coursework) will also be used in this case study to strengthen and verify our results from the interviews.[71,72,76–78] This rich data set allows for an in-depth case study and triangulation of data from multiple sources.[71,72,76]

4.5.3 Data Analysis

4.5.3.1 Applying Theoretical Frameworks for Interpreting Nick's Experience

Nick's ability to overcome his mathematical challenges and create stepping-stones on his path to his career goal is why Miller and Brickman's theory, which integrates future time perspective and self-regulated learning, was an appropriate model to begin mapping his experience. He had the future goal of being an Air Force pilot, a distinct subgoal of graduating with an engineering degree, and within that subgoal were even more subgoals, one of which was to pass the required calculus courses. Prior knowledge, future goals, and the creation of subgoals, or a contingent path, follow the future-oriented part of the Miller and Brickman model, which will help describe why he didn't quit or change majors. The process by which he was able to motivate himself and work through the barriers he faced while progressing through the engineering program are supported and explained by the proximal self-regulation part of the Miller and Brickman model.

4.5.3.2 Coding and Interpretation of Data

Deductive coding[79] was used when analyzing the interview transcripts, where the elements within Miller and Brickman's model served as the pre-determined codes. Transcripts were analyzed using RQDA, an R package used to code qualitative data. Internal validity was established using pattern matching, which compares and matches data from multiple sources.[71,76,80] When patterns were found that didn't correspond with an element in Miller and Brickman's model, a new code was created. Once all themes were identified, the transcripts were examined again to identify all possible connections between the elements. Several iterations were conducted before finalizing the mapping of Nick's story to the new model. A full list of model items, descriptions, and examples, as well as examples of the connections, are listed in the codebook in Appendix B.

The open-ended survey and interview transcripts which had been coded as 'Proximal Task Engagement and Self-Regulation' were then subcoded in RQDA, this time using a codebook established from Zimmerman and Martinez-Pons' 14 self-regulation strategies.[2,60] Seeking social assistance from peers, teachers, or adults were consolidated to a single category, seeking social assistance, also referred to as help seeking.[56,57,59,81] Likewise, reviewing records from tests, notes, or textbooks were consolidated to just reviewing records. A copy of the codebook is provided in Appendix C. Pattern matching was again used to compare codes between the different data sources.[71,76,80]

4.5.4 Quality Considerations

Several techniques were used to improve the inferences from the data. First, sufficient time was spent with Nick in conversation during his final semester to build a relationship and get a good understanding of his story from his own perspective.[77,82] He was an easy student to interview in that he opened up quickly and wasn't shy about elaborating when asked questions about his experience. Second, by utilizing multiple sources of data, the findings could be triangulated.[71,76,77,82–84] Interviews from his mother, advisor, and instructor, along with his academic transcript confirmed his self-reported journey. Throughout the research project, meticulous notes were taken so an outside researcher could follow the process.[71,76,82] Lastly, this chapter was shared with the participants.[76,77,84] No corrections were necessary, but more details were included for clarification purposes.

4.6 Results

4.6.1 Overview of Nick: Past Experiences and Values

Nick was raised in a large city on the Atlantic coast in the south. At the age of 10, Nick's father became ill and passed away. His mother explained that:

> At the age of 10, if you lose your dad, there's a lot of things that go on. I think at that point he and I embarked on that struggle of grief together. Our philosophy was you just have to keep going. You have to put one step in front of the other. You have to be able to overcome, no matter what.

He and his mother developed a very close bond. It became clear from the interviews that he often hears her when he is faced with decisions. For example, he had a few courses in college for which he felt that attendance wasn't always necessary, but "It's like I can't bring myself not to go, and I think it is mostly because of mom saying [in high school], 'You've got to go to class. You've got to get up and go to class.' "

Throughout his youth Nick participated in sports and church activities. He formed a bond with many of the coaches and church members. His devotion to his religion continued into college when he helped start a Christian fraternity on campus. As an athlete in grade school, he quickly developed into a leader for the younger kids and understood the corresponding responsibility. "If I wanted the younger kids to be doing good in school, then I needed to be doing good in school ... Me showing value in the grades at the same time and showing that basketball and football are a privilege after you perform in the classroom." Nick enjoyed his leadership role and wanted to be recognized as a leader in future endeavors.

4.6.2 Nick's Future: Interest, Future Goal and System of Proximal Subgoals

Nick attended a very small, private, Christian school with grades kindergarten through 12th. Because it was a new school, the administration pulled in teachers to get the curriculum established. After completing an assignment in history class on World War I ace Eddie Rickenbacker, his teacher (the wife of one of the male figures in the church, who had also served in the Air Force) asked Nick if he had considered going into the Air Force. At the time he hadn't considered it, but after considering this over the next several years, Nick finally decided he wanted to be an Air Force pilot (Future Goal). He was not accepted into the Air Force Academy straight out of high school so decided to attend college elsewhere. It was important to Nick to find a way to pay for college. "I always wanted to get school paid for so mom didn't have to worry about that." So he pursued an ROTC scholarship. He filled out the ROTC scholarship application indicating he would major in an engineering discipline (subgoal), something he knew the Air Force was looking for (which was confirmed by his ROTC advisor), and was given a full scholarship and five years to complete the degree program.

Luke was one of Nick's ROTC advisors at the university. While he wasn't retired when he was advising Nick, Luke has since retired from the military after serving for more than 25 years. As Nick's advisor, he was charged with helping Nick map out his degree program, including all of the courses he would be required to take, and helping him stay on track so he could graduate on time. Luke did this for roughly 50 students each semester. As an engineering major, Nick was required to take several math courses, including calculus I – III. These math courses serve as proximal target goals and contingent steps necessary for the engineering degree. Nick understood the importance of these math courses for his engineering degree (perceived instrumentality). Nick saw the required calculus courses as having exogenous instrumentality for his future goal, because he did not believe that he would use calculus as an Air Force pilot,[45] but if he couldn't complete the required mathematics courses, he wouldn't graduate with the engineering degree he deemed necessary to be an Air Force pilot.

At our university, freshmen engineering majors start in a common first year engineering program. They cannot matriculate into an engineering major until they've completed certain courses, including calculus I and II. Through the open-ended survey, Nick revealed he originally wanted to go into mechanical engineering, but when Luke realized mathematics wan't one of Nick's strengths, he encouraged Nick to major in industrial engineering. At our university, industrial engineering only requires calculus I – III, while mechanical engineering requires three additional mathematics courses, all with calculus III as a prerequisite. Even Nick recognized the importance of strong math skills for mechanical engineering: "I was originally thinking mechanical engineering, but I was struggling with math early." Luke's influence on Nick's decision to pick industrial engineering is represented in the model by the connection from External Reactions (Advisor) to System of Proximal Subgoals.

4.6.3 Nick's Mathematical Ability Entering College: Past Experiences, Knowledge/Retention, and Self-Concept of Ability

Nick explained that his troubles in mathematics began in middle and high school when a teacher for algebra I and II was brought in who didn't seem to care and didn't follow the standard curriculum. When Nick moved on to precalculus, they had a different teacher who assumed the students knew algebra, but quickly became frustrated when he realized they had deficiencies he didn't have time to fill. The school ended up bringing in another teacher midway through the year to finish the precalculus course, but as Nick observed, he "still didn't learn as much as I needed to in that second half."

Before starting at our university, all new students are required to take a math placement test to determine which mathematics course in which they should begin. Without Advanced Placement or transfer credit, Nick could place into either precalculus, long calculus (calculus I over two semesters), or calculus I. The placement test was scored on a scale of 1 to 6. Students earning a 5 or 6 on the placement test were placed into calculus I. Students earning a 3 or 4 were placed into long calculus. Those with a 1 or 2 began in precalculus. Typically students took about an hour to complete the 50 question placement test. Because the Mathematical Sciences Department time stamped when a student started and completed the test, and because I have access to placement test details, I was able to see that Nick spent more than an hour and a half on the test and scored a 1. Half of the placement test questions covered algebra only. His weighted subscore for the algebra questions was 10.25 out of 25, indicating he was very weak in algebra. This weakness persisted even in his second semester of college. Figure 4.2 is an example of Nick's work from a problem he worked out in his introductory engineering course. At one point he needed to solve for R, the value of of a resistor. It was a very basic equation, $15 = .4R$, but instead of just writing the solution to a straight forward division operation, $R = 37.5$, Nick needed to explicitly divide both sides by .4 first and cross out the form of one. Explicitly writing out this step is an elementary step college students would be expected to skip.

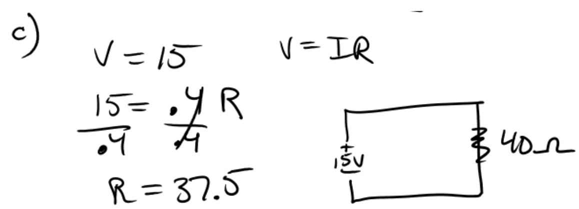

Figure 4.2: A sample of Nick's work from his introductory engineering course

Nick attributes his mathematical deficiencies with the poor instruction he was given in high school. Because of this, he never questioned his ability to complete an engineering degree. When asked if he thought a person who's not a math person could be a good, successful engineer, he replied with:

> I think that if math isn't your best strength, but you have the motivation to get through and that sort of stuff, then that's definitely possible, and that you don't need to know everything behind there, but you can still do it. (Nick)

When I asked his mom, advisor, and calculus II instructor why they thought Nick had a difficult time with college mathematics, they all said they thought it stemmed from poor preparation in high school.

> The math teacher that he had in junior high there was some inconsistency there when one of the algebra teachers ... I think it was just the methodology... if you've got a good teacher that can communicate clearly and teach algebra, it lays the foundation for the rest of the classes beyond that. If you don't have a teacher that can teach, she may know in her head what she's doing, but she can't portray that to the kids. So I think that was the bottom line. (mom)

> [Nick's] struggle was really math. Good at everything else and I think he just didn't have the tools from high school that would allow him to be successful easily, at all easily. (Luke, ROTC advisor)

> One of the real weaknesses I found for him, which I think is typical of a lot of students, he just did not have the necessary background. He did not know the algebra and trig and geometry. (Morgan, calculus II instructor)

4.6.4 Where and How Nick Struggled: Proximal Target Goal

Because of poor algebra I and II instruction in high school, Nick entered college with significant mathematical deficiencies which were evidenced by his math placement test results, placing him in precalculus, the lowest level course a student wanting to major in an engineering discipline can begin in. After taking the mathematics placement test before his freshman year, Nick understood he was behind in mathematics. "With the Air Force, they let you take 5 years. It's like, okay, well I have some extra time so I can take this extra class, [precalculus], and be able to catch back up in the math." He recognized that the material was important for subsequent courses, but because of how the course was graded, he didn't put in as much effort as he later realized he should have. "One of the things that probably made it easier not to work as hard was the fact that it was pass or fail. Okay, well, I'm going to need this stuff later, but it's pass or fail." Adding to that was the fact that he was in Arnold Air, a military society, where he had to get up around 4:00 in the morning and then was expected to attend an 8:00 math class.

> I was trying to pay attention in that class, but it's 8:00 in the morning after I just got out of two back to back PT's . . . I'm already worn out and tired and all that stuff and then, like I still was going to class . . . I just wasn't in prime learning mode.

He passed precalculus his first semester, but "at the end, I knew that I wasn't doing really well, but I knew it was enough to pass."

The following semester Nick completed calculus I. Nick recognized that he had holes going into calculus I. "I didn't do as good in [precalculus] as I should have, then that kind of carried over to [calculus I] also." While he passed the first calculus course with the C required by engineering to move on to calculus II, he barely earned it. His test grades from calculus I were 78, 53.5, 60, and a cumulative final exam grade of 52. The class averages for the exams were 75, 75.3, 70.1, and 59, respectively, indicating he had below average performance on all but the first exam. While his test grades indicate he wasn't mastering the material, his daily average (94.3) indicates he was putting in the effort and time needed to complete daily assignments and homework. He finished the course with a 70.02 average, just 0.53 points above receiving a D and having to repeat the course.

The fall of his second year he took calculus II with Morgan, a faculty member in the mathematical sciences department. Nick realized he didn't retain as much of the calculus I material as he would need. "I had holes in [calculus I]." It wasn't going well, and he didn't want an F on his transcript, so he decided to officially withdraw from the course, but asked Morgan if he could continue to attend class and take notes.

> 'Sure, that's fine with me,' [I told him]. And, I guess one of the first things that impressed me, I've had students through the years that always ask me that and then they may show up one or two more times and that's it. Hardly ever have anyone actually do it all the way to the end and he did. He came, I think nearly every class, participated in everything we did. (Morgan, calculus II instructor)

The next semester he retook calculus II, but this time had an instructor who was also serving in an administrative capacity in the department. Nick tried to get assistance during office hours, but it wasn't as helpful as he had hoped. "He didn't have a whole lot of time outside of class and he made it known that that was the case. I didn't feel comfortable going to him and the times that I did, he was very short and it's like 'we went over this in class'." Nick felt alone. "You feel like you have a lack of options as far as what to do. So you feel like you just have to sit there and struggle when you don't have anything else that you can do or anybody else you can kind of turn to for help."

Nick ran into Morgan one day, and when they discussed how class was going, Nick explained he was still having a difficult time in calculus II. Morgan offered to let Nick come by the office and ask questions if he wanted help. Nick asked if the offer was a serious one, and when Morgan confirmed, Nick took advantage of the offer. "I got better, I just didn't get enough to kind of repair the damage." This is evidenced by Nick's test grades that semester. He made a 36.5 on the first exam. His test grades increased on each subsequent exam, with a 54 on the second, 58.25 on the third, and a 68 on the final exam. And again, his daily average (94.66) showed he was trying. This was enough for him to pass the course with a D, but because engineering at our university requires a C or higher in prerequisite courses, it wasn't enough to move on to calculus III.

What his transcript doesn't show, but what came out in an interview with him, is that he tried to take calculus II the following summer after he made the D in order to transfer it in and count as the required C, but he "couldn't keep up. Especially with the shortened summer [class]". He took the course a fourth time the fall of his third year. This time he worked with Morgan from the beginning and finished the course with the required C.

Throughout college Nick didn't fail any of his courses. He made the one D in calculus II, but ended with nine Cs. An interesting point when analyzing his transcript is that eight of those Cs were either in mathematics courses (calculus I, II, and III) or courses that are very math oriented (engineering problem solving, probability and statistics I, statics, probability and statistics II, and physics with calculus II). Because it took four attempts for Nick to achieve the required grade of C in calculus II, this is the course chosen to primarily focus on as the Proximal Target Goal in the model.

4.6.5 Revised Model of Connections Between FTP and SRL

After analyzing the interviews, Miller and Brickman's model was modified to explain Nick's mathematical experience (see Figure 4.3). Items and connections indicated by dashed lines were not in the original model, but were identified while coding the interview transcripts as something that could augment Miller and Brickman's model to explain the data in this case study. General & Task-Specific Problem Solving and Learning Strategies from the Miller and Brickman model was later changed to Personal Responsibility by Brickman.[85] Personal responsibility has been defined as a student's "overall level of commitment to completing established personal goals even when they are difficult".[85,86] This item change accurately reflects Nick's experience in that he had to, and chose to, repeat calculus II multiple times in order to continue in the engineering program.

4.6.5.1 New Model Items

Nick developed a strong interest in not only becoming an Air Force pilot, but also in engineering. This came out in the data analysis of statements from Nick such as "I always liked planes, so if I could be flying planes then I'd definitely do that." and "I knew that I wanted to do engineering. I think it was mostly because it was more hands on. It was problem solving, I like that part of it." His mother said, "Mechanically Nick has always been very interested as far as cars and engines and movement and that just transpired into flight." Part of his motivation for becoming a pilot and majoring in engineering was his inherent interest, and thus, it warranted a place in the model.

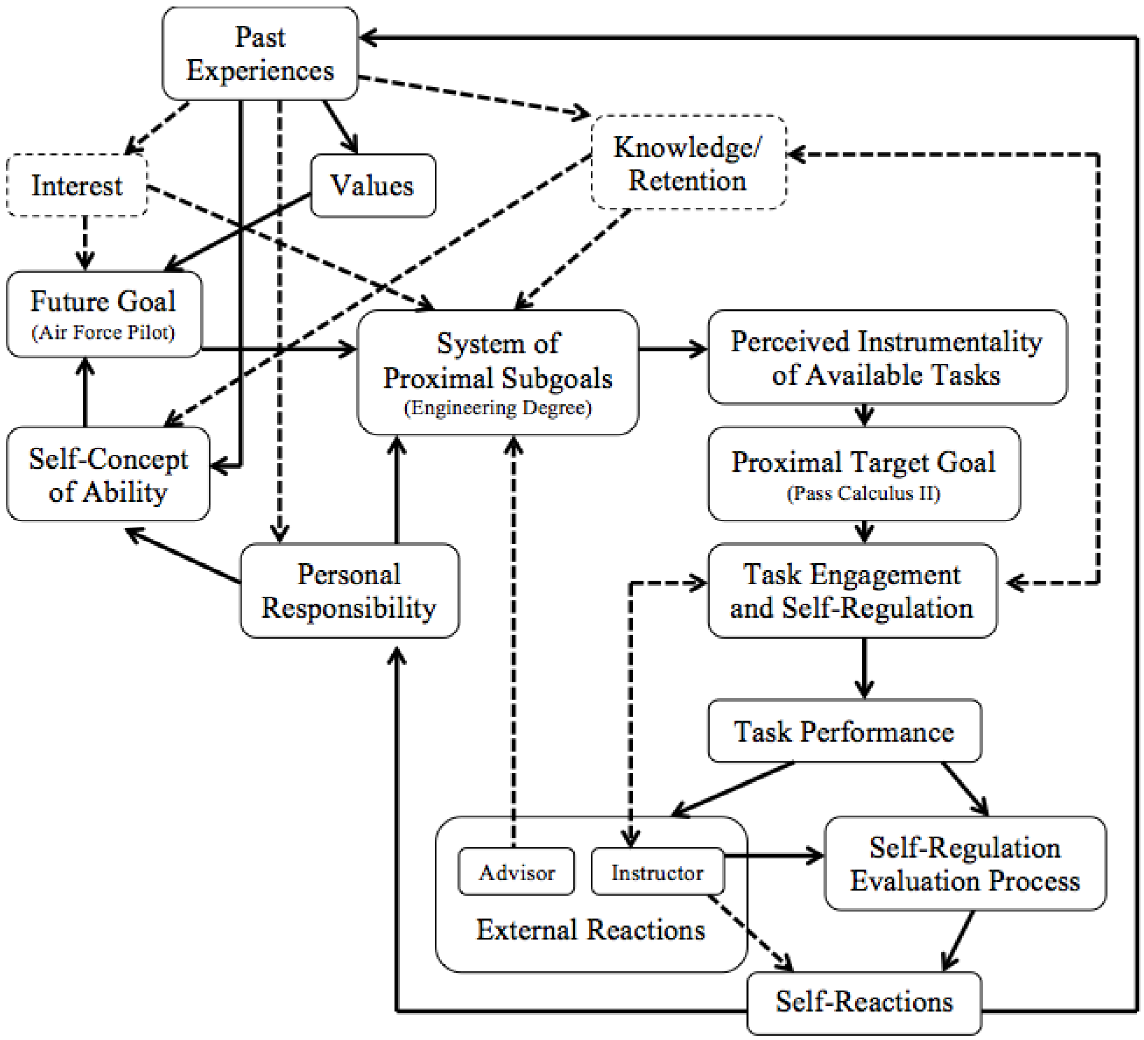

Figure 4.3: A model of connections between FTP & SRL based on Nick's experience

The fact that he didn't have the necessary mathematical knowledge to excel in calculus and had a hard time retaining the information from one course to the next also frequently became evident during interviews. His poor math background and inability to retain as much as necessary was the reason he had to repeat calculus II as many times as he did. Because of that, it was important that knowledge and retention be added to the model of his experience.

He had not retained as much of the [calculus I] material in detail like we

> needed so he was constantly struggling and asking those questions, well why... Well, what you were supposed to get in [calculus I]... (Morgan, calculus II instructor)

As Nick was working through math courses, he was drawing on his previous knowledge and putting more to memory. This relationship between knowledge acquisition and retention and learning can be seen in the model by the two-way connection between Knowledge/Retention and Task Engagement and Self-Regulation. This connection is supported by cognitive learning theory related to how new ideas interact with one's prior knowledge, creating new meaning which is then linked, organized, and retained in memory.[87,88]

4.6.5.2 Items Removed from Miller and Brickman's Model

Nick was determined to become an Air Force pilot. To do that, he was convinced he needed to major in engineering. Because he didn't even consider alternatives, Knowledge of Possibilities which appears in Miller and Brickman's model didn't apply to him and so was excluded from the study model. Also appearing in Miller and Brickman's model, but excluded from the study model, are Perceived Immediate Context and Available Tasks, Task-Related Outcome and Efficacy Expectations, Cognitive Evaluation of Context, and Present Task Value. The purpose of this study is to clearly explain why Nick didn't quit and how he was able to make it through those barrier courses when he was mathematically weak. It was thought that specific assignments in his courses did not add more insight into his experience. When task is referred to in the study model, reference is made to the current semester course he is working through, rather than specific assignments within that class.

4.6.6 Instructor's Influence on Nick's Success: Task Engagement and Self-Regulation

Nick and Morgan worked together in the afternoons, on some weekends, and even late in the evenings, sometimes past midnight. When asked how often they met during his fourth attempt at calculus II, Morgan's response was, "I think it would be easier to ask when we didn't meet. It got to the point I think it was like nearly every afternoon." The relationship Nick and Morgan developed, and the importance of it to his success on his path to an engineering degree, is represented in the model by the two-sided connection between External Reactions (Instructor) and Task Engagement and Self-Regulation.

4.6.6.1 Nick's Self-Regulation Strategies

On the open-ended survey and during the interviews, Nick was asked about his math courses and how he was able to overcome difficulties with the material. Several of Zimmerman and Martinez-Pons' self-regulation strategies[60] were identified during analysis of the open-ended survey and the interviews with Nick.

Goal Setting and Planning

When Nick withdrew from calculus II, he chose to continue attending and participating in class. This was a plan on his part to make sure he was prepared for the next time he attempted to take the course. While he was working with Morgan, they had tutoring sessions frequently, but Nick also made it a point to plan sessions before an exam.

Information Seeking

Nick mentioned that in one of the last semesters of calculus he started using online resources to help him understand the material. When I asked him what kind of things he would try when he was stuck working a homework problem, his response was:

> Like looking up stuff online. I don't even know if I knew that really existed when I got here freshman year, but the Khan Academy stuff. I'd try to look up stuff online later and that helped. And I ended up kind of trying to use that to study later on and stuff too.

Keeping Records and Monitoring

Nick made it a point to attend class regularly. "It's like very, very rare that I miss class." Even after he withdrew that one semester, he continued to attend and participate in everything they did. These show signs of monitoring his education. Nick did not make explicit reference to keeping records.

Rehearsing and Memorizing

On the questionnaire, when asked how he was able to overcome mathematical challenges, he said "Reading over the chapter before class helped a lot." and "It also helps going home and practicing the same stuff you learned in class that day that night." Both reading before class and reworking course problems are examples of rehearsing the material.

Seeking Social Assistance

This is unquestionably the most influential strategy Nick used. Nick would ask for help when he needed it. He would go to student-lead instruction sessions outside of class and ask questions. He would visit tutors at the university tutoring center to get help on the course material. He tried asking all of his instructors for help in office hours. When Morgan offered to help Nick the first time they ran into each other, Nick continued to seek Morgan for assistance. Even after that first semester, Nick continued to visit Morgan's office and ask for help on the calculus material over multiple semesters.

Self-evaluation

During interviews Nick brought up being confused in class, but not wanting to ask questions. He didn't want to stop and ask the teacher in class because "it is so fast-paced . . . if you ask a bunch of questions and you're not getting it, then you're not getting taught the rest of the stuff that needs to be taught." He didn't want to ask the other students sitting next to them because "they're trying to focus on the class too and the teacher's still going so, you know, it's almost distracting them from learning." When discussing the frustration he felt when he went to the administrator's office hours, he said "yeah, you might have gone over this in class 10 minutes ago, but I didn't understand it. And so, if I didn't understand that, I need you to explain it to me again." All of these examples show Nick was able to self-evaluate and determine when he wasn't understanding the material.

4.6.6.2 External Regulation Strategies

Nick attributes his eventual success in calculus II to Morgan, who privately tutored him over the course of several semesters. During their sessions together, Morgan modeled self-regulation strategies for Nick.

Environmental Structures

When Nick was having a hard time focusing or was getting tired during their tutoring sessions, Morgan would have him go outside and jog or do calisthenics.

> [Morgan] would be 'Alright, let's do some push ups.' It wasn't anything like you have to do this or anything else. It was like, 'You've got to wake up, let's go for a quick jog real quick, get your blood flowing again.' That was great in that part of it too and the motivation behind that. You've got to keep working, you've got to keep working and even working those long hours and stuff, that was really motivational for me too. (Nick)

Morgan confirmed this during the interview when asked to describe when Nick was getting frustrated or struggling.

> One of the funny things I finally discovered was because of his ROTC background, I would sometimes make him do calisthenics and go out and run. Anything to try and get some energy out, or get him pepped up again. That actually seemed to work, and I was really shocked, because, actually, I was in a classroom one day working and it seems like he had a test or something coming, and he was not doing good that day. I was like, 'Okay, either you've got to get in focus or we need to stop because it's not helping.' [Nick] said, 'No, we can't, we can't. We've got a test.' I said, 'Well, how are we going to get you focused?' [Nick] said, 'I don't know. I don't know.' I was sitting there and I thought, he's ROTC. I know he loves sports. I thought, okay, come here. I took him outside and I just started drilling him. He did not flinch one time. It was like okay, okay. Then we went back upstairs. I said, 'Now, go to the board and do those problems.' It actually worked. He got a big kick out of it too. (Morgan)

Morgan would also take Nick down to one of the classrooms and let him work problems on the board. Morgan attended to Nick's individual needs by changing the environment, which helped Nick get in the right frame of mind and focus in order to continue working through the calculus problems.

Rehearsing and Memorizing

When Nick and Morgan got together, it was often the case that Morgan would work an example problem using the concept Nick was asking about and then Morgan would give Nick problems to work through himself, changing each problem slightly, increasing the level of difficulty. Nick explained it as:

> [Morgan] was like, 'Okay, this is the example.' Then [Morgan would] put one on [the board] that was almost the same thing or there might have been a 2 in front of it or something like that. It's like okay, 'What do you think you do for this one?'. 'Okay, this is what you do for this part.' 'You're right. That's exactly what you're supposed to do.' [Morgan] was like, 'Well, now it's x^3. What do you think you do?'. [Morgan would] let me figure that out [before saying] 'well, actually you've got to do this . . . '. And so, having that building instead of having the one base example and then you kind of have to figure it out for the rest of the stuff . . . [Morgan would say] 'this is what you're going to do for this one because of this reason, and this is why this has to go here.' [Morgan] did a very good job as far as explaining that stuff. I think that was what really made the difference because you don't have to get that in class.

Working through problems in a repetitive nature is considered rehearsing.

Keeping Records and Monitoring

Because they met frequently, Morgan kept a running list of where the two of them had left off at the end of their session and the concepts they needed to review or still needed to cover. Monitoring their progress and keeping a record of what needed to be addressed again next time is another example of Morgan attending to Nick's needs.

Nick relied on Morgan's model of self-regulation strategies to help him get through the course material.

> There's no way that I'd be able to do well in any of my math classes, and I still didn't do very well, but there's no way I would have lasted without [Morgan's] help. (Nick)

Even after Nick completed calculus II with a C, he continued to meet with Morgan while taking calculus III, but not as frequently. "[Calculus III] wasn't nearly as bad... I just thought it was more straight forward than some of those things. Maybe the subject matter was easier too." (Nick)

4.6.7 Why Nick Didn't Quit or Change Majors: Personal Responsibility

When Nick was having a hard time with calculus and briefly thought about changing majors, he quickly chose to stick with it.

> It's like yeah it might be hard, but you're going to work your tail off and you're going to get through this; you're not going to quit. If you're going to quit it's going to be because this is not what you want to do, not because you're not getting the grades you want. You can work harder or you can go. (Nick)

This 'can't quit' attitude came up several times and when asked about it during interviews, both he and his mother attributed a lot of that to how his mother raised him and their philosophy of 'you just have to keep going'. This is represented in our model by the connection between Past Experiences and Personal Responsibility.

When Nick applied for the ROTC scholarship, he put engineering as his intended major. According to Luke, the students who put engineering have a much better chance of being awarded the scholarship. Nick knew the Air Force was looking for people with a technical degree like engineering. Once he received the scholarship, Nick was contractually obligated to major in engineering and complete the program within 5 years. If he decided to change majors, he would lose the scholarship and might have had to pay back the money he already used. Nick was determined to get out of school debt free, so changing majors and losing his scholarship was not an option for him.

Between his scholarship and his commitment to finishing what he started, changing majors to something outside of engineering was never a real consideration. He needed the scholarship, was determined to join the Air Force, and wanted all of the opportunities that would come with that if he had a technical degree.

4.7 Discussion

4.7.1 Overall Findings

This case study illustrates how, even with a poor mathematical background, a student with a clear future goal, who was able to create a path of subgoals to that future goal, and who was willing to seek out help and guidance from others when encountering obstacles (two of Zimmerman's strategies of self-regulation[60]), was able to successfully complete an engineering degree. A student's understanding of the importance of current tasks, such as needing to pass calculus II, on attaining their future goals has been found to increase student motivation, performance, and persistence.[41,89,90] Students who can see the connection between current tasks and a future goal are more likely to stay on track.[41,44] Students who begin their engineering studies in non-college level mathematics may need help creating goals and understanding why what they are doing now is important, and how it relates to not only their current goals, but their future goals.

While Miller and Brickman's model combining self-regulation and future time perspective has been used in multiple studies, it has not been applied to undergraduate engineering students.[1,68,85,91–93] This case study shows how this model can be adapted to explain an engineering student's commitment to their future goal and how critical required courses, i.e. contingent steps, are to reaching that future goal. This is particularly relevant for engineering because engineering students at our university aren't able to transfer out of the introductory engineering program and declare an engineering major until they've completed core prerequisite courses. A student starting in precalculus isn't permitted to take the introductory engineering course, so staying motivated and finding ways to self-regulate during those foundational courses is extremely important.

At our university, mandatory orientations are given the summer before a student matriculates in the fall. First year students come to campus for two days and attend many informational sessions. They also meet with their academic advisors for the first time and create their first semester schedules. This is a good time to outline a study plan and explain university resources available to students. Recent research on undergraduate students experiencing academic difficulty showed that a goal-setting program improved performance and retention.[94] Understanding how Nick used subgoals to help him achieve his future goals could provide advisors with the tools needed to support and guide new students in the creation of a clear path of subgoals and to keep them on track to reach their future goals. Faculty members and advisors can not only help a student map out their path of required courses to graduation, but can explain the consequences of getting off course. Had Nick not passed calculus II, he couldn't have stayed in engineering, would have lost his scholarship, and wouldn't have entered the Air Force with the opportunities and advantages that came with having a technical degree.

A key to Nick's success was choosing an engineering discipline that isn't as calculus-dependent as other engineering disciplines. In advising circles and amongst students, it is well known that mechanical engineering is a calculus-dependent engineering discipline, while industrial engineering has the reputation of being one of the easier engineering disciplines.[95] Upper division industrial engineering courses focus more on operations research, programming, and statistics, instead of calculus, which might be why it is perceived by others as being easier. In a work-in-progress study of over 150,000 engineering undergraduates at eleven public universities, Lord, Layton, and Ohland showed among the five major engineering disciplines (chemical, civil, electrical, industrial, and mechanical), industrial engineering was the only discipline to add students between matriculation and six-year graduation.[96] Students like Nick who have weak math skills can be identified very early on based on their placement test score. Advisors can recommend students with poor math skills who are determined to major in engineering to consider one of the less calculus dependent disciplines, like industrial.

Through this case study, it was shown that Nick utilized several self-regulated learning strategies,[60] including goal setting and planning, information seeking, rehearsing, and self-evaluation. However, his most influential strategy was seeking the help of a mathematics instructor, Morgan. Seeking assistance when needed is expected of self-regulated learners.[56,57,59,60,81,97] It is important that students know when to ask for help and how to have effective tutoring sessions that will lead to not only mastery of the current task, but long-term autonomy.[59,81]

Nick was fortunate in that Morgan modeled several regulation strategies for Nick. Morgan would have Nick go outside and exercise to get him re-energized when Nick was having a hard time focusing. Morgan would also have Nick work problems on the board in one of the classrooms. Changing the study environment is a resource management strategy Morgan used to help Nick regulate.[56–58,97] Morgan also helped Nick 'rehearse' calculus problems, working through multiple problems covering the same concept. Morgan would continually provide Nick with feedback while they worked through problems on the board. Morgan was helping Nick plan, monitor, and evaluate his work.[57,60] Because of Nick's poor mathematical background, he was relying on Morgan to compensate for his deficits in processing and self-regulating calculus tasks.[98]

Research shows students benefit from learning self-regulation strategies. After students on academic probation took a course on study strategies, Renzulli found the amount of time each student spent studying increased, with the average time studying increasing from 8.0 hours to 19.4 hours.[99] While students starting in precalculus aren't on academic probation, they are coming in with mathematics deficiencies and can benefit from a course on study strategies. Similarly, Tuckman and Kennedy found a first year course on learning strategies had a positive impact on grade point averages, retention and graduation rates.[100] Just the act of summarizing a lecture (a cognitive learning strategy) after taking notes has been found to increase retention of material over simply reading over one's notes.[101] At the University of Pretoria in South Africa, students entering the School of Engineering with deficiencies enter a five year program, instead of a four year program.[102] They've created a course for students in the five year program which teaches both math skills and study skills concurrently with calculus I. The students in the five year program who take this course were shown to have similar graduation rates compared to those who started in the four year track.

Engineering students at our university who start in precalculus aren't eligible to take the introductory engineering course, physics or chemistry until they've passed precalculus. As a result, they are advised to take general education courses or creative inquiries. Weinstein and Mayer published a framework for describing the teaching-learning process and discuss ways of teaching learning strategies, including rehearsal, elaboration, organization, monitoring, and motivational strategies.[103] Several universities have created learning-to-learn courses to teach and promote self-regulation strategies.[104] Learning-to-learn courses have been shown to increase mastery orientation and self-efficacy for learning and decrease test anxiety.[105] They have also been shown to improve GPA up to five semesters after the course was taken.[106] Researchers have pointed out one limitation of courses that only teach learning strategies is transferability.[104–106] Are students able to use the skills from the learning-to-learn courses in their major courses? Taking a course on learning strategies within the context of engineering, where they set an academic future goal and a path of subgoals, could prove to be valuable for precalculus students' success once they get into the engineering program. However, just because students are taught the skills needed to succeed academically doesn't mean they will use them. Self-regulated learners have to have the motivation to commit to achieving their academic goals, as well as the volition to follow-through.[97]

4.7.2 Limitations

One limitation of this study is that it was a case study on a single student.[71,78] While one can't generalize based on a single student's experience, one can learn from it.[72,73] Nick's difficulty in calculus stemmed from poor instruction in high school, in particular, poor instruction in algebra I and II. Successful completion of algebra II has been found to be a measure of college readiness,[107] and algebra skills have been found to predict calculus I success.[108] Our university's mathematics placement test assesses students' algebra skills and when weak, places them in precalculus. Because precalculus is graded pass/fail, this case study suggests that students might not put in as much effort into the courses as they would otherwise, as was the case with Nick. As educators, we can stress the importance of the course material on subsequent course success and help students with strategies for retaining the required knowledge.

Another limitation is that much of the explanation of Nick's successful completion of an engineering degree stems from Nick's personality. Nick was clearly a very determined person. While much of his 'can't quit' attitude can be explained by the way he was raised, even his mother admits some of that is "just DNA and that factor of who he is. And, he sets his mind to something, and it's going to happen." A personality trait isn't something we can teach or coach to our students. However, we can share Nick's experience and present him as a role model for students who struggle. His strategy to persevere and through determination and effort succeed, one subgoal at a time, until the goal is met could be inspirational to other students.

Not necessarily a limitation, but something worth discussing is Morgan's willingness to help Nick as much and for as long as Morgan did. Morgan is a faculty member in the Mathematical Sciences Department. While required to hold office hours for current students, instructors are not required to hold office hours for past students, stay late in the afternoon or in the evening, come up on weekends, or work countless hours with students. As Nick witnessed, some faculty members are not as willing to put in the time to help students or to meet their individual needs. Nick was very fortunate Morgan was willing and able to spend many hours with him.

4.8 Conclusion

While in grade school, Nick had a dream to become an Air Force pilot. His strategy to major in engineering helped him secure a scholarship that would enable him to reach his goal. As part of his engineering degree program, he was required to take certain mathematics courses, including a known barrier course, calculus II.[21] Despite his poor mathematical knowledge, skills, and ability, he was able, with the help of a mathematics instructor and mentor, to eventually pass the course with a C. Each time he failed to meet the goal, he had to re-evaluate and decide if he wanted to stay with engineering and to take the course again. Because of his contract with the government (under which he kept the ROTC scholarship if he graduated with an engineering degree), and because of his own 'can't quit' attitude, he found a path to success in the engineering program. He wasn't willing to change majors from engineering because changing majors would have meant the end of his dream. He instead persevered and succeeded. By exploring the experience of one of the few successful students, the self-regulation strategies of goal setting, changing environmental settings, and help seeking were identified and proved valuable to his success.

Chapter 5

Conclusions

5.1 Addressing the Research Subquestions

What are the graduation rates for engineering students with different initial mathematics courses?

Engineering students entering the university with Advanced Placement credit who begin in calculus II or III have the highest six-year engineering graduation rates at 68.50% and 78.49%, respectively. For students starting 'on track' in calculus I, the graduation rate is 65.41%. For engineering students coming in with mathematical deficiencies, who start in precalculus or long calculus, the six-year engineering graduation rates are only 19.08% and 40.43% respectively.

In what ways did the student struggle?

Nick struggled both academically and socially in his mathematics courses. He entered the university with algebra deficiencies and therefore had to begin in the lowest level math course an engineering major can. While he successfully completed both precalculus and calculus I his first time through, his poor math background left holes that that couldn't be filled and resulted in him having to take calculus II four times. He found himself looking for help wherever he could. He tried supplemental instruction, tutors in the academic success program, and asking his instructors for help. One of his instructors wasn't willing to give him the time or help he needed, so Nick gratefully took advantage when a previous instructor offered to help him.

How did the student get through the required mathematics courses?

Nick's first calculus II instructor, Morgan, offered to work with Nick during his subsequent attempts taking the course. While Nick utilized several self-regulating strategies himself, like goal setting and planning and rehearsing and memorizing, Morgan modeled self-regulation strategies for Nick. In particular, Morgan changed Nick's environment and made him go outside and do calisthenics when he was having a hard time focusing. Morgan would 'rehearse' mathematics problems with Nick. Morgan had a way of explaining the concepts that allowed Nick to understand the material and practice problems on his own, something Nick wasn't getting out of his instructors at the time.

Why didn't the student give up or change majors when he was required to retake required courses multiple times?

Nick was raised to pick himself back up and keep going when things knocked him down. Since he was a child, if he was determined to do something, he found a way to get it done. Nick was determined to be a pilot in the Air Force. He received an

ROTC scholarship to major in engineering and became contractually obligated to do so within five years. Given his contract with the government and his own ‘can't quit’ attitude, he never seriously considered changing majors or quitting.

5.2 Addressing the Overall Research Question

If an engineering student starting in calculus is more likely to graduate with an engineering degree than one starting in precalculus, how does a student complete an engineering degree program after struggling through mathematics courses?

This research shows the initial mathematics course an engineering student places into significantly predicts the odds they will complete an engineering degree program. Engineering students beginning in precalculus, the lowest level course a new engineering major can begin in, are looking at an uphill battle compared to students beginning in one of the calculus courses. For engineering students starting in precalculus, almost half of the students change majors or leave the university within a year of their first semester.[23] Not even 20% of the students starting in precalculus graduate with an engineering degree within six years. This is significantly less than those starting in calculus I (65.41%).

By studying the experience of one of the few students who began in precalculus and successfully completed a degree in industrial engineering, we were able to see the importance of future goals and self-regulation. With the help of his ROTC advisor, Nick mapped out the required courses to complete the engineering degree needed to fulfill his ROTC scholarship in a timely manner. Because he had everything planned out, goals set and the motivation to achieve those goals, self-regulation was triggered to help him get through the required courses.

While Nick admitted he struggled with all of the calculus courses, he really had a tough time with calculus II, having to take the course four times. Nick used several self-regulation strategies while trying to get through the course with a passing grade, but he attributes his eventual success to the help of a mathematics instructor. The instructor tutored Nick more afternoons than not over the course of multiple semesters. Nick was shown by the instructor how changing his environment and taking study breaks helped him stay focused. Their 'rehearsing' of calculus problems kept the material fresh. Even though Nick entered the program with mathematical deficiencies, he had the motivation to stay with engineering, and he had the volition to follow-through, seeking help when needed.

5.3 Implications for Research

This research used a theoretical framework from Miller and Brickman that combined future time perspective and self-regulated learning to explore an engineering student's experience as he struggled through his mathematics courses, but was able to overcome those challenges. This study adds to the limited literature on this particular framework. Interest was added to the model to further explain why a student chose particular future goals and proximal subgoals. Knowledge and retention was added to the framework to help explain the relationship between what a student knows from previous educational experiences, what they are learning during current educational tasks, and how it relates to their system of goals and concept of ability to achieve future goals. Another unique contribution of this study was to provide a deeper understanding of how a student with mathematical deficiencies is able to pass the second semester calculus, a known barrier course to students seeking engineering degrees. Future work will need to consider experiences of multiple types of students at multiple institutions, but the insight from this one student is a step in establishing an appropriate framework for studying the experience of engineering students who lack the prerequisite knowledge to start in calculus.

5.4 Implications for Practice

With graduation rates so bleak for engineering students starting in lower level mathematics courses, it is imperative that these students are advised properly while in first year engineering. Poor and inadequate advising has been a documented reason students leave engineering.[13,25,27,109] Our university uses centralized advising for first year engineering students until they have passed the required courses and can declare an engineering major. Centralized advising has been shown to increase GPA and persistence over no advising or general education advising,[26,110] so our university is on the right track, but more can be done for students placing into precalculus.

This research shows some engineering disciplines may be more attainable for students starting in non-college level mathematics courses. Because these students are identified by their placement test score before they even arrive on campus, they could be advised which disciplines they are more likely to be successful in. Once an engineering discipline has been chosen, advisors can help students create their contingent path of courses to degree attainment.

Making sure these students have the right tools in their toolbox to complete an engineering program is also something educators can focus on. This research shows that self-regulating strategies are key to get through required courses. While these students are ineligible to take their engineering courses, they could be taking courses on self-regulation learning strategies within the context of the future goals and subgoals they have set. We should teach and model these strategies until they can adapt them as their own.

Appendices

Appendix A

Open-ended Survey and Interview Protocols for Case Study

A.1 Open-ended Survey

Please answer the following questions with as much detail as possible. If you need more space, please add additional paper or continue on the back.

1. What was your intended major when you entered college?
2. Has your declared/intended major changed since you started college? If so, why?
3. Please describe your ideal job after graduation.
4. Please describe the three most crucial influences (people, experiences, school-related subjects, etc.) on your career choice in order of most to least important. Include how each has influenced your career choice.
5. Please describe the characteristics needed to be an engineer.
6. On a scale of 1 (not at all) to 7 (very much), do you see yourself as an engineer?
7. Describe the ways in which you see yourself as an engineer.
8. What do you want to do with a career in engineering?
9. Describe a scenario/experience in which you felt recognized as an engineer.
10. Do you feel engineering can have an impact on the world? How?
11. Describe three ways in which science and engineering impact your life personally.

12. On a scale of 1 (not at all) to 7 (very much), do you see yourself as a math person?
13. Describe the ways in which you see yourself as a math person.
14. Describe a scenario/experience in which you felt recognized as a math person.
15. Which math courses, if any, do you feel you excelled in?
16. What about those courses allowed you to do well? Be specific.
17. Which math courses, if any, did you really struggle with?
18. What about those courses did you find particularly challenging? Be specific.
19. How were you able to overcome those challenges? Be specific.
20. Have you found the math courses you were required to take important to your major? How so?

A.2 Initial Interview - Nick

Choice of Engineering

- Why did you choose to come to Clemson? (did you apply to other schools; what made you choose Clemson over others)
  - When did you decide to come to Clemson?
  - What/who was most influential in making this decision?
- Why did you choose engineering?
  - When did you decide to major in engineering?
  - What/who was most influential in making this decision?
  - What experiences do you have outside of the classroom related to engineering? (co-op, internship, research, creative inquiry, etc.)
  - Did the Air Force affect your decision to major in engineering?

Influencers

- Are there any advisors/instructors/professors in engineering who have motivated you about becoming an engineer, or really gotten you excited about the field of engineering?
  - What did they do?
  - How much of an influence did they have on your decision to stay in engineering?
- Do any of your previous math instructors stand out, for either positive or negative reasons?
  - What did they do?
  - Describe ways that made you feel recognized, made you feel competent, helped you through struggles, etc.
  - Describe ways that they didn't support your efforts, discouraged you, or made you feel incompetent, etc.
  - How did you respond to that ...
- Who are the most influential people in your life in terms of school and career?
  - What is it that they do that has influenced you?
  - How much of an influence have they had on you? (For example, do you think you'd be majoring in engineering without their influence?)
- Are there people in your life that have discouraged you in your major/career choice?
  - What are their reasons?
  - Describe how you would respond to them.
  - Have you considered changing majors/careers because of them? Describe that decision.

Math and Engineering

- On a scale from 0 - 10 (0 not at all, 10 extremely), how important is math for an engineer? For an industrial engineer?
- Can a person not be a math person and still be a successful engineer? Why or why not or how?
- What math skills do you view as important for your profession? You mentioned basic math skills, but what do you mean?

Barriers

- Discuss the barriers you faced in your math courses.
  - mentioned standardized tests, elaborate
- How were you able to overcome these difficulties? (tutoring, SI, etc.)
  - Explain more about your times spent with Morgan during office hours. Did you attend with other students? How were the sessions run?
- When you had difficulty in your math courses, did you consider switching to a non-engineering major?
  - If so, to what, and why didn't you?
  - If no, why not?

Resources - get contact info if need to interview someone

- What kind of extra-curricular activities (clubs, teams, ROTC, employment, etc.) have you been involved in at Clemson? How long have you been involved with them?
- When did you decide you wanted to do these extra-curricular activities?
  - Who/what was the biggest influence in your decision to join these extra-

curricular activities?

- How has being in these extra-curricular activities affected your choice of engineering as a major?
- What resources are/have been available to you for courses because you are in these extra-curricular activities?
  - Which of those have you used?
  - On a scale from 0 - 10 (0 not at all, 10 couldn't have done it without them), how helpful have they been?

A.3 Interview - Advisor (Luke)

- Discuss what your roll was in the ROTC program.
- Discuss reasons why a student wanting to go into the military, in particular, the Air Force, would major in engineering instead of something else?
- If a student intending to major in engineering came to you while struggling in their calculus courses, what advice would you give them? If they were set on engineering, still in general engineering, but interested in ME, would this advice change?
- I am conducting a case study on Nick. He started in general engineering in Fall **** and will be graduating this semester with an Industrial Engineering degree. He mentioned you were the ROTC advisor when he first started. Do you remember him? If yes, what in particular do you remember? (work ethic, motivation, determination, etc ...)

A.4 Interview - Instructor (Morgan)

I am conducting a case study on Nick. He is going to graduate with a degree in Industrial Engineering this semester. He mentioned repeatedly in a questionnaire and an interview that you had a huge impact on his education.

- Can you discuss how your relationship with Nick began?
- Can you give me an idea of how your sessions would go?
- Why did Nick struggle? How did he react to your criticism/help? Please describe a specific incident when Nick struggled with a problem. How was he able to move on?
- How often would you meet?
- How many semesters and courses did you help him with?
- Can you describe him as a student (work ethic, motivation, determination, etc ...)? Describe an instance where ... based on what he says.
- Did you ever consider telling him to give up or change majors? Why, or why not?
- Over the last 5 years, how many students like Nick have you dedicated a significant amount of time to? If not many, why him?

A.5 Interview - Mom

- Can you describe when Nick decided he wanted to join the military? Why do you think he wanted to?
- Can you describe when Nick decided he wanted to major in engineering?
- Can you describe why you think Nick struggled in his math courses?

- When I asked Nick if he ever seriously considered changing to an easier major, he said no, and that he can't quit. His "never quit" attitude came up a few times in the interview. Can you describe where you think this attitude came from, and why it stuck with him?

A.6 Follow-up Interview - Nick

- I want to get a better picture of your high school math classes. Can we lay out what courses were available, and which courses you took which year?
  - Which courses did you struggle with, or had 'that teacher' for?
  - How did you decide which courses to take?
  - How well do you feel that your high school math classes prepared you for college? For majoring in engineering?
- What were the consequences of starting in precalculus in college?
  - Were there other courses you couldn't take because of it (particularly in engineering)?
  - Did you have to stay in college longer? If yes, describe any consequences (i.e. did it cost more, or affect your choices for a career after graduation).
  - Consequences in terms of taking calculus 1 the next semester? Did it prepare you; was it necessary for success?
- Can you describe what it means to struggle in a course?
- Which of your math courses at Clemson did you struggle in?
  - Which engineering courses at Clemson did you struggle in? Were these struggles a consequence of your math background)?
- Can you describe how you felt when your were struggling?

  - What were your thoughts while struggling on a particular problem?
  - What were your thoughts while struggling in a course?
  - If you were working on homework and were having a really hard time, what things would you do to move on?
- What would have happened had you decided you couldn't do the math and couldn't get through the engineering program?
  - What were your alternatives?
  - Were there other majors you could have selected?
  - Would you still have been able to go into the same program you will be in the Air Force?
- Describe how engineering gives you more opportunities after graduation.
  - Do you think that is the same for other military branches?

Appendix B

Codebook for Future Time Perspective and Self-Regulated Learning Model

B.1 Individual Codes

Table B.1: Codes used in case study - adapted from Miller and Brickman's Model[1]

Code	**Definition**	**Meaning for Nick**	**Example from case study**
External Reactions	What others expected[85]	How others responded to him, helped him, impacted him while he was on his path to graduating	Instructor tutored him, advisor steered him toward a less calculus-dependent engineering discipline
Future Goal	A self-relevant, self-defining, personally valued future goal: life task, possible self, career, etc[1,93]	What he wants to do, be, have in the future; what's important for him to accomplish	Air Force fighter jet pilot
Interest	An individual's general attitude or liking that is somewhat stable over time and a function of personal characteristics[57]	What he enjoys or thinks he would enjoy pursuing	"I have always loved planes and other things with motors"

Code	Definition	Meaning for Nick	Example from case study
Knowledge/ Retention		What he currently knows and his ability to write something to long-term memory and recall it later	"One of the real weaknesses I found for [Nick], . . . , he just didn't have the necessary background. He did not know the algebra and trig and geometry." (Morgan)
Past Experiences	Sociocultural factors that have influenced what's important, including family, peers, school, and media.[93]	What has happened to him, around him, in the past that has impacted his current and future self	Dad passed, bond formed with a former member of the Air Force, mom raised him with a 'we don't give up' mentality
Perceived Instrumentality of Available Tasks	The implications of a current task on their future goals[41]	How important he sees current tasks as being necessary in attaining future goals	Needed calculus II for engineering, needed engineering for ROTC scholarship
Personal Responsibility	"Level of commitment to completing established personal goals even when they are difficult"[85]	His 'can't quit' attitude	Took calculus II four times, but refused to change majors
Proximal Target Goal	Current task one is pursuing[1]	Current goal he's trying to achieve	Pass calculus II

Code	Definition	Meaning for Nick	Example from case study
Proximal Task Engagement and Self-Regulation	Cognitive, motivational, and behavioral strategies used to complete a task[85]	What he's doing to accomplish the current task, the amount of effort he is putting in, his thought process	Tutoring/study sessions with math instructor. "He loved working at the board. We would go to the classrooms and I would just write problems on the board and he would work on them and we'd discuss" (Instructor)
Self-Concept of Ability	The perception that one believes they can accomplish distant future goals[93]	His belief that he can accomplish his subgoal(s) in order to reach his future goal	"It was like, 'Alright, you can do this. It may be hard now, but you can get through it' " (Nick)
Self-Reactions	Evaluative (positive or negative) and tangible (rewarding or punishing) response to one's behavior and actions[50]	How he reacted to his performance in math courses, his decision to stay in engineering, etc.	"There's no way that I'd be able to do well in any of my math classes, and I still didn't do very well, but there's no way I would have lasted without [Morgan's] help."
Self-Regulation Evaluation Process	Evaluation of performance[85]	Reflecting on how and what he did in class	"I knew I wasn't doing well. I knew that I wasn't getting, you know, something wasn't clicking."
System of Proximal Subgoals	A path of objectives one sets for themselves which will lead to attaining their future goals[1,93]	Path to his future goal	"The people who get slots [in the Air Force] are all engineering. It's all technical majors. Because I mean, that's what they need right now." (Luke)

Code	Definition	Meaning for Nick	Example from case study
Task Performance		How he did in his courses (for this study completing a course is his current task)	Withdrew from calculus II, took it again and made a D, tried taking it over the summer, but failed, passed with a C on his fourth attempt.
Values	Perceptions of what, how, and why certain things are important and worth pursuit[93]	What's important to him and driving some of his decisions	He wants to be a leader, serve the country, make his mom proud, and wanted to get out of school debt free

B.2 Connections Between Codes

Table B.2: Connections between model codes

From Code	To Code	Example from case study
External Reactions (Advisor)	System of Proximal Subgoals	Luke advised Nick to switch from mechanical engineering to industrial engineering when it became clear Nick was having a hard time with his mathematics courses.
External Reactions (Instructor)	Self-Reactions	"[Morgan] did a very good job as far as explaining [how a complex problem can be decomposed to something more manageable]. I think that was what really made the difference because you don't have to get that in class."

From Code	To Code	Example from case study
External Reactions (Instructor)	Self-Regulation Evaluation Process	"I mean if you're really smart, you're a math person then maybe you can put all those things together, but my brain and with all the holes I had, I couldn't do that without [Morgan] piecing it together for me."
External Reactions (Instructor)	Task Engagement and Self-Regulation	"I also kept a running list of things I felt like we needed to keep working on and we would discuss the ideas, and I would give him some problems and say, okay, show me what you can do..." (Morgan)
Future Goal	System of Proximal Subgoals	"With the Air Force, it's a lot more likely that you'll get a training slot or whatever if you're in engineering." (Nick)
Interest	Future Goal	"I always liked planes, so if I could be flying planes then I'd definitely do that."
Interest	System of Proximal Subgoals	"I knew that I wanted to do engineering. I think it was mostly because it was more hands on. It was problem solving. I like that part of it."
Knowledge/ Retention	Self-Concept of Ability	"... if I don't have all the background for this and it's like, I can't do this on my own because even if I read this study and went through al the things by myself before class, all this other stuff, then I'm still going to be lost."
Knowledge/ Retention	System of Proximal Subgoals	He dropped dynamics, a math-heavy engineering course he was struggling with, but because he switched to industrial engineering and they no longer required it, he didn't have to try again.

From Code	To Code	Example from case study
Knowledge/ Retention	Task Engagement and Self-Regulation	Each time he was working through a math problem, he was pulling from his math memory.
Past Experiences	Interest	He completed a history assignment on a WWII pilot. His teacher's husband was in the Air Force. She asked if he considered joining. As he said, "the seed was planted".
Past Experiences	Knowledge/ Retention	He had a horrible algebra I and II teacher in high school so he entered college with mathematical deficiencies.
Past Experiences	Personal Responsibility	"Our philosophy was you just have to keep going. You have to put one step in front of the other. You have to be able to overcome, no matter what." (Mom)
Past Experiences	Self-Concept of Ability	"I'm not a math person, so from experience, but I'm very hands on. I can understand math concepts and that part of it."
Past Experiences	Values	"I was challenged early to develop as a leader and I haven't wanted to stop ever since."
Perceived Instrumentality of Available Tasks	Proximal Target Goal	To keep his ROTC scholarship, he had to major in engineering. And in order to major in engineering, he had to pass calculus II with a C or higher.
Personal Responsibility	Self-Concept of Ability	"I think that if math isn't your best strength, but you have the motivation to get through and that sort of stuff, then that's definitely possible, and that you don't need to know everything behind there, but you can still do it."

From Code	To Code	Example from case study
Personal Responsibility	System of Proximal Subgoals	He was willing to change from mechanical engineering to industrial engineering because it was still engineering. So to him, he wasn't quitting.
Proximal Target Goal	Task Engagement and Self-Regulation	After he withdrew from calculus II the first time he took it, he continued to attend the course and take notes.
Self-Concept of Ability	Future Goal	"None of those really popped like the Air Force stuff did. I was like, okay, well, this is what I'm going to do." He never doubted his ability to make it in the Air Force.
Self-Reactions	Past Experiences	Each math course he took, regardless of how he did, became a past experience after he reflected. He then chose to enter the cycle again committing to his future goal and system of subgoals.
Self-Reactions	Personal Responsibility	"If you're going to quit, it's going to be because this is not what you want to do, not because you're not getting the grades you want. You can work harder or you can go." (Nick)
Self-Regulation Evaluation Process	Self-Reactions	"I tried to take [calculus II] over the summer which was a bad idea, because I couldn't take it over the whole summer. It was like the shortened one and it was super fast."
System of Proximal Subgoals	Perceived Instrumentality of Available Tasks	If he didn't keep his grades up, or if he changed majors from engineering, he'd lose his ROTC scholarship.
Task Engagement and Self-Regulation	External Reactions (Instructor)	When Nick was having a hard time concentrating during their study sessions, Morgan would have him go outside and do some calisthenics to get him 'pepped up again'.

From Code	**To Code**	**Example from case study**
Task Engagement and Self-Regulation	Knowledge/ Retention	"He couldn't seem to always put it together as fast or retain it like he wanted to." (Morgan)
Task Engagement and Self-Regulation	Task Performance	"that's when I was really buckling down with [Morgan] and stuff and doing that and got through that one."
Task Performance	External Reactions	When Nick said he was struggling with calculus II Morgan offered to tutor him.
Task Performance	Self-Regulation Evaluation Process	"[Calculus II at a technical college] was still tough, couldn't keep up, especially with the shortened summer stuff."
Values	Future Goal	"The Air Force is perfect for [being a leader] and I know that as long as I stay in the Air Force, I will continue to develop as a leader."

Appendix C

Codebook for Self-Regulation Strategies

Table C.1: Subcodes used for Self-Regulation Strategies[2]

Category	Pre-given Examples
Environmental Structures	• avoid distractions • change life habits (eating, sleeping, etc) • change study environment • find a quiet place to study
Giving Self-Consequences	• use reward system
Goal Setting and Planning	• attend class more regularly • manage time • pace • plan studying/study sessions • review every day or periodically • review several days before exam/ahead of time • set study goals • start homework early • study the hardest material first • take study breaks
Information Seeking	• check class resources (book, internet, videos, etc.) • fill in notes • read the syllabus • use campus resources (i.e. library, test banks, etc.) • use example methods from class to solve problems
Keeping Records and Monitoring	• ask questions in class • engage in class • listen during lecture • manage attention • self-monitor • sit in front/center of the classroom • take notes • write questions down

Category	Pre-given Examples
Organization and Transformation	• create note (summary) sheet • write summaries of class materials • highlight key ideas • keep organized notes • reorganize notes • take notes about book or readings • transform material • work real world problems
Rehearsing and Memorizing	• attempt problems before class • make flashcards • preview before class • read before class • repetition • reread the book • rewrite notes • rework course problems • work problems (from book, online, etc.) • skim the textbook • use the "study cycle" • utilize memorization techniques • write down equations
Reviewing Records	• discuss lecture content • read reading assignments • review class materials • review every day or periodically • review examples • review homework • review materials for test • review notes from professor • review old notes just before class • review same day • review worked problems in book
Seeking Social Assistance	• ask a tutor • ask advisor • ask campus resources (person) • ask for help • ask other students • ask teaching assistant • ask teacher • group work

Category	**Pre-given Examples**
Self-Evaluation	• create problems • evaluate after exam • evaluate studying • make sure to understand • review at end of study session • self-test

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