Effects of Mismatched Math Self-Efficacy and Performance on Behaviors and Attitudes of Engineering Students with Poor Math Preparation

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EFFECTS OF MISMATCHED MATH SELF-EFFICACY AND PERFORMANCE ON BEHAVIORS AND ATTITUDES OF ENGINEERING STUDENTS WITH POOR MATH PREPARATION

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ABSTRACT

This research is a sequential explanatory mixed methods study seeking to understand the influences of mathematics self-efficacy (math SE) on the behavior and attitudes of engineering students with poor math preparation behavior and attitudes in their first college math courses.

The quantitative phase of this research assessed the math SE of engineering students placed in non-college-level math courses at Clemson University. A total of 408 students completed a survey to classify their math SE level; based on the results of the quantitative data analysis, 11 engineering students were selected from different semesters between the Spring 2014 and Spring 2016 to be interviewed during the qualitative phase of this research.

Following a constructivist grounded theory approach for the qualitative data analysis, each of the eleven students’ interviews was coded and analyzed before conducting the interview with the next participant. Findings of the grounded theory were compared and analyzed together with the quantitative results during the final mixing phase. This mixed analysis determined that these students’ choice of behaviors and attitudes in college math courses depended on their math SE beliefs and how these beliefs aligned with their mathematics competence/knowledge.

All interviewed students reported a relatively high math SE ranging from 6.2 to 9 (out of 10), but further analysis of their performance in their college math courses revealed differences in students’ descriptions of their math SE beliefs and their math competence/knowledge levels. This mismatch between students’ math SE and
competence/knowledge affected students’ behaviors and attitudes in college math courses. Students with math SE beliefs matched to their math competence/knowledge reported to be more likely to spend extra time working to overcome their math deficiencies, and to seek extra help to address their doubts. However, students with math SE beliefs higher than their math competence/knowledge reported to be more likely to procrastinate and put poor effort into improving their math abilities, blaming external factors for their struggles in college math courses. On the other hand, students with math SE beliefs that were slightly lower than their math competence/knowledge reported to be more likely to spend extra time working on math related activities and to take their struggles learning math as opportunities to improve their math abilities.

Despite showing different behaviors and attitudes in math courses, these engineering students were confident that their math competence/knowledge would help them to complete all the math courses required by their majors. These students stated that they were likely to persist in engineering even if they face struggles in their math courses in the future due to their high math SE beliefs performing math in general.
DEDICATION

This work is dedicated to my advisor, Lisa. There were too many factors that made this research one of the most challenging tasks that I ever faced, and your constant support, motivation, advice, and patience were key during the entire process. I didn’t lie when I told you that this experience changed the way I breathe. You helped me to develop good abilities as a researcher with your expertise in the field of STEM education, but your friendship, kindness, and passion about your work motivated me to continuously improve as a human being. I look forward to working with you in the future.
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Although this work is listed under my name, it is really a sum of efforts from all my friends in the ESED department. The help and constant support of my research group, my SoCap girls, my writing buddy Rachel, and all ESED faculty members was very instrumental for this work. I would always be thankful for everything you did for me, especially Jenn who was my math partner during the entire process.

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CHAPTER ONE

INTRODUCTION

1.1 Motivation for this Study

Engineers are important to the economic development and growth of a country (Committee on STEM Education, 2013). If any country is unable to train enough engineers with the necessary skills to design and create new technological solutions to current society needs and problems, then this country will face setbacks in its development (National Academy of Engineering, 2015). In spite of the clear importance of training enough engineers, the projected demands for professionals in STEM fields surpasses the projected supply of trained STEM graduates in the next decade (Committee on STEM Education, 2013), resulting in a possible shortage of new engineers. This potential shortage of professional engineers could become a real problem if U.S. universities fail to match the projected 756,000 new engineers that will be needed to cover all job openings in the U.S. between 2012 and 2022, according to the U.S. Department of Labor on its Bureau of Labor Statics (CRS, 2012). Despite the need and importance of more trained engineers, the number of students earning degrees in engineering or engineering-related technologies in the U.S. has significantly decreased since 1985 (Snyder & Dillow, 2010).

There are many different factors that could influence a student’s decision to choose engineering as a career, depending on their background (Lent et al., 1994), precollege academic experiences (Porter, 2011), parents’ influence (Verdín & Godwin, 2015), and math ability and preparation (Lent et al., 1991; Nicholls, Wolfe, Besterfield-Sacre, Shuman, & Larpkiattaworn, 2007). Other students may become interested in engineering
because of their desire to help people through building things and designing machines, even if they do not completely understand what is involved in engineers’ daily work and preparation (Cunningham & Knight, 2004). Although the recruitment of new students into engineering majors is one problem, keeping these students in these majors is also a current issue. STEM career attrition rates were around 50% between 2003 and 2009 (Chen & Soldner, 2013). Reasons for students leaving STEM fields have been correlated to different causes, including students’ demographic characteristics, precollege academic preparation, STEM courses they choose to take, and performance (Chen & Soldner, 2013). Therefore, it is important for universities to find ways to address high attrition rates for the students in STEM majors.

The lack of adequate math background for some students who want to become engineers is a big challenge for current engineering educators. Once these students decide to pursue an engineering major, math competence/knowledge becomes a key role in their education. Engineering students must complete several math courses in which they need to understand high level concepts and applications. The concepts and applications learned in math courses are later applied in advanced engineering courses, making it impossible to graduate with an engineering degree without a solid mathematical background (Kokkelenberg & Sinha, 2010). However, there is much variability in the level of high school mathematical preparation for students entering college (Porter, 2011). Once enrolled, math courses like Calculus I and II have been identified as barrier courses for engineering students, and struggling to complete this courses could discourage students trying to get an engineering degree (Suresh, 2006). Students typically struggle to complete
these advanced math courses; their high withdrawal and failure rates create negative feelings towards college Calculus courses, and they often refer to these courses as ‘weed out’ courses by both students and instructors (Seymour & Hewitt, 1997). Students that are more likely to struggle with the Calculus concepts are the ones that get to college lacking the skills necessary to be successful in the college-level math courses. These students come to college with deficiencies in their math competence/knowledge, and they usually score poorly in their math SAT (Suresh, 2006). The quality of the math education that some students receive before college could affect their math competence/knowledge development, and some populations such as Latino, African-American and first generation students are more likely to have some deficiencies in their math preparation due to the lack of opportunities (Flores, 2007; Lee, 2012). Students with poor math preparation are required to start in non-college-level math courses, and research suggest that students starting in a math course lower than Calculus I are less likely to persist in engineering (Middleton et al., 2015; Van Dyken, Benson, & Gerard, 2015). Current literature suggests that students’ confidence in successfully performing math-related activities could help them to persist in math courses, and help them continue to try to improve their math abilities if they face some struggles performing math (Hackett, 1985; Lent et al., 1991).

1.2 Background

The self-efficacy concept emerged in the late 70s when Bandura (1977) suggested that personal beliefs concerning people’s abilities to successfully perform a specific task could be a major determinant in people’s decisions to attempt that task, and could also affect the effort that people are willing to expend to complete that task if they face
struggles. This self-efficacy concept was later included in vocational and career behavior research, aiming to develop a broader understanding of peoples’ decisions to pursue a particular major (Bandura, 1980; Hackett, 1985; Lent, Brown, & Larkin, 1984; Zimmerman, 2000). Findings of early self-efficacy research positioned it as an important motivational factor that may influence students’ interest in pursuing a specific major, and persisting in their desire to complete that major despite struggling and facing obstacles in the process (Bandura, 1986; Hackett & Betz, 1989; Lent, Lopez, & Bieschke, 1991; Multon, Brown, & Lent, 1991).

According to Bandura (1986), self-efficacy refers to “people’s judgments of their capabilities to organize and execute courses of action required to attain designated types of performances.” (p. 391) The majority of studies analyzing self-efficacy rely on quantitative approaches to assess people’s self-efficacy levels in any giving task, using surveys to rate self-efficacy beliefs (Purzer, 2011; Walker, Greene, & Mansell, 2006; Williams & Williams, 2010). Although surveys in these studies addressed different tasks, researchers were aiming to measure participants’ level of confidence in performing those tasks successfully. These self-efficacy items were normally organized based on Bandura’s guide for constructing self-efficacy scales (Bandura, 2006), using questions to rate participants’ level of confidence performing a specific task on a scale from 1 (not at all) to 10 (very confident). Although very few, some studies used a qualitative approach for understanding the relationships between self-efficacy and performance, persistence and choice of actions (Brown & Burnham, 2012; Jenson, Petri, Day, Truman, & Duffy, 2011). These qualitative studies used interviews and focus groups for data collection, aiming to get richer
information of the different self-efficacy sources and how this self-efficacy could evolve and modify participants’ choice of behaviors in their academic experiences.

These different qualitative and quantitative approaches of collecting self-reported self-efficacy are widely used and have shown to be accurate in assessing people’s beliefs about their skills performing specific tasks (Blackwell, Trzesniewski, & Dweck, 2007; Graham & Harris, 1989; Redmond et al., 2007; Williams & Williams, 2010). The validity and credibility of these instruments were typically established by consulting experts and experienced researchers for face and content validity of the interview questions (Jenson et al., 2011; Moran & Benson, 2015), and statistical analyses such as exploratory factor analysis and Cronbach’s alpha for quantitative surveys (Betz & Hackett, 1983; Williams & Williams, 2010).

1.3 Mathematics Self-Efficacy

Self-efficacy beliefs have been included in research aiming to determine what motivational factors could affect students’ interest in pursuing a STEM major. Findings of these studies show that students who felt that they had a good math preparation in their precollege academic experiences, which helped them to develop a high math self-efficacy (math SE), were more likely to show interest in pursuing a math-related major like engineering (Hackett, 1985; Lent, Brown, & Hackett, 1994; Lent et al., 1991). The importance of understanding engineering students’ math SE levels can be seen in the different reactions that people normally have when they have low or high self-efficacy for performing a specific math tasks. Low math SE levels have been shown to have an influence on students’ decisions to avoid math-related activities that may lead them to
stress and anxiety feelings (Cooper & Robinson, 1991). If students avoid extra work and effort to improve their math abilities to avoid fostering these negative feelings, then the possibility of overcoming their math deficiencies decreases, and they will be more likely to quit trying to develop their skills and abilities. Conversely, the literature suggests that after experiencing success in mathematics activities and seeking assistance when they are uncertain, students’ math SE may increase (Bandura, 1986).

This relationship between math SE and performance has been shown to work both ways, with performance affecting math SE and with math SE modifying choices, performance, and persistence in specific math tasks (Williams & Williams, 2010). The influence of math SE on students’ performance in math courses and activities has shown to be significant, and this significance has been confirmed in different contexts, cultures, and populations (Cooper & Robinson, 1991). The consistency in the relevance of math SE not only on students’ performance but also on their choices and persistence when they are facing struggles to understand math topics, is a good indicator of the importance of this motivational factor in students’ math preparation. Prior research has shown that students’ math SE was lower for students leaving STEM majors like engineering, and this factor was more significant for students quitting school during their first college semesters (Eris et al., 2010).

The relationship of self-efficacy beliefs and performance could be interactive (Armstrong & Vogel, 2010), and there may be some discrepancies between these two factors during the students’ math learning process (Moran & Benson, 2016). These discrepancies may change and evolve according to students’ experiences; ideally, students
would have a more equilibrated and realistic perception of their math abilities after having enough experience taking challenging math courses (Redmond et al., 2011).

1.4 Purpose

The purpose of this research is to deepen our understanding about students’ math SE beliefs, and how these beliefs affect academic performance, behaviors and attitudes in their first math course for engineering students with poor math preparation. For the population in this study, students are considered as having poor math preparation if they scored below the necessary grade to start in Calculus I on the Clemson Mathematics Placement Test (CMPT). This research is seeking to help decrease engineering attrition, especially for students that experience difficulties with mathematics courses due to a poor mathematical high school background that is reflected in low mathematical competence/knowledge. If we develop a better understanding of the experiences of engineering students with poor math preparation in their first math courses at college, educators could better address the needs of these students. Although there is much that is known in general about the relationship between students’ math SE and their performance in college mathematics courses (Hackett & Betz, 1989; Siegel, Galassi, & Ware, 1985; Williams & Williams, 2010), there is little research analyzing the specific case of possible effects of math SE on performance when engineering students struggle understanding the material in their first college mathematics course due to poor math preparation. Research focusing on a deeper understanding of the relation of students’ math SE with their performance could be beneficial for math educators, helping them to develop strategies aiming to motivate
and guide their students, especially when these students are facing struggles and negative results in their first college math courses.

This research was guided by following research questions:

R.Q. 1 How does math SE of first year engineering students with poor mathematics preparation influence their performance, behavior and attitudes in their first college mathematics course?

R.Q. 2 How well does math SE reflect students’ actual competence/knowledge, and what are the implications of a mismatch between the two?

R.Q. 2.1 What are student behaviors and attitudes in math courses when there is a mismatch between math SE and competence/knowledge (low math SE and high competence/knowledge; high math SE and low competence/knowledge)?

R.Q. 2.2 What are student behaviors and attitudes in math courses when their math SE and competence knowledge levels are well matched?

R.Q. 2.3 What are the effects of a mismatch or a match between math SE and competence/knowledge on students’ confidence in completing the math courses required for an engineering degree?

For the purposes of this study, student behaviors are defined as the decisions that students make regarding time expended trying to understand their class material, time expended working on their homework assignments, their reaction if they struggle with specific topics, and their decisions to take advantage of or ignore the extra resources
available for the class (software, teaching assistants (TA), supplemental instructors (SI), office hours, tutors, etc.). Student attitudes refer to their feelings and emotional reactions about performing math-related activities in general and about their current mathematics course.

Despite the importance of math SE and its influence on engineering students’ choices of behavior and performance, the math SE beliefs for engineering students with poor math preparation have not been studied before. This is where this study will expand current literature, analyzing the different behaviors and attitudes of engineering students with poor math preparation depending on their math SE and how well these math SE beliefs match their actual competence/knowledge. Students may react negatively if they show a relative big gap between a high math SE and a low math competence/knowledge. Overconfidence about their math abilities could create a false sense of security and minimize the role of practice and extra work in achieving expected results (Lent et al., 1994). On the other hand, students showing a relative low math SE with a higher math competence knowledge may feel insecure performing challenging math activities, even when they may be able to successfully perform those activities with their current math competence/knowledge level (Moran & Benson, 2015).

Understanding possible students’ reactions to setbacks and poor performance in math classes based on their math SE may help engineering educators to develop strategies to keep students motivated and engaged in classes. Differences in students’ math SE could lead students with similar cognitive abilities to perform at different levels; this difference in performance could be due to differences in the effort that students exerted when they
struggled or faced difficulties performing math (Lent et al., 1994). This extra effort and stronger will to succeed despite adversity is known as grit (Duckworth, 2016; Perkins-Gough, 2013) or coping efficacy (Lent, Brown, & Hackett, 2000). Understanding more about the effects of math SE and performance on students’ coping efficacy could help math educators to motivate engineering students to continue pursuing their long term goal of getting an engineering degree. Keeping engineering students motivated to persist and continue taking math courses despite facing struggles could help engineering educators to address the high attrition rates in engineering majors (Geisinger & Raman, 2013), especially for under-served groups and minorities that are more likely to quit if they face obstacles due to their poor math preparation (Flores, 2007; Lent et al., 2000).

1.5 Theoretical Frameworks

Two different frameworks will be used to inform this study. Developed by Bandura (1986), Social Cognitive Theory highlights cognitive, vicarious, self-regulatory, and self-reflective processes that modify people’s behavior and choices. Within Bandura’s social cognitive constructs, self-efficacy has a key role predicting one’s choice of activities, effort expenditure, persistence and emotional reactions when facing difficulties performing any particular task. The development of these beliefs is related to the skills one possesses, but these beliefs can be different from one’s actual knowledge and abilities.

The social cognitive view of self-efficacy is a dynamic set of self-beliefs about one’s ability to perform a specific task. These beliefs are task specific: one’s skills in a particular task may influence only the individual performance on that task (Bandura, 1986). It is important to understand that self-efficacy beliefs could be related to objectively
assessed skills, but these two factors could also be very different depending on one’s experiences and circumstances. To have a more accurate performance prediction based on self-efficacy beliefs, it is generally necessary that the individual’s skills match their self-efficacy beliefs; or at least that the difference between their abilities and self-confidence about these abilities to be relative small. Bandura’s theory hypothesizes that self-efficacy beliefs that slightly exceed one’s current skill level could encourage people to try challenging activities that may promote better skills development. On the other hand, self-efficacy beliefs that grossly exceed or underestimate current skill level could lead to maladaptive behavior; a discrepancy with high self-efficacy without good skills that support these beliefs could lead to failure or poor performance in challenging activities, while pessimistic beliefs or lack of confidence in well-developed skills may prompt avoidance of activities that are within one’s competence range. Unrealistic perceptions of one’s abilities performing a particular task could generate different behaviors that may affect one’s performance and the way that skills develop depending on the activity environment and context.

Self-knowledge about one’s efficacy is based on four principal sources: (1) performance attainments, where repeated successful experiences make you feel confident about your abilities; (2) vicarious experiences, where you learn by observing the performance of others; (3) verbal persuasion, where different types of social influences make one believe that possesses certain capabilities; and (4) physiological states, from which people judge their capabilities depending on their feelings performing an activity (Bandura, 1986). Research suggests that performance attainment is the most influential
factor affecting self-efficacy for a specific task (Hackett, 1985), but the other three sources (vicarious experiences, verbal persuasion, and physiological states), described by Bandura are still important in trying to improve someone’s self-efficacy if that person has performed poorly before, or is currently struggling with any task (Lopez & Lent, 1992).

Bandura’s theory (1986) suggests that a person’s self-efficacy beliefs could be modified through any of the four sources cited, but the difference in this self-efficacy will be lagged by a buffer effect. This buffer effect means that good performance or positive feedback about any activity will not turn into better self-efficacy immediately. It is necessary that successful experiences and good performance happen often to really affect self-efficacy levels in that specific task (Bandura & Schunk, 1981).

Other important constructs supporting the Social Cognitive Theory are outcome expectations and goal setting. These constructs help individuals to establish courses of action and are related with self-efficacy in career and academic theories. For this specific research, self-efficacy will be the only social cognitive theory constructs analyzed, trying to understand its relation with performance and persistence in engineering majors. Self-efficacy was chosen due to its hypothesized direct and indirect effect on performance, influencing it through outcome expectations and goal setting.

The Social Cognitive Career Theory (SCCT) framework is derived from Bandura’s (1986) Social Cognitive Theory. SCCT framework identifies three social cognitive mechanisms relevant to career development: (a) self-efficacy beliefs, (b) outcome expectations, and (c) goal representations (Lent et al., 1994). These three constructs are the core of the three models developed through this framework, which are:
interest development, career choice, and performance. These models are significantly directly or indirectly related to self-efficacy beliefs, making a connection between interest, career choices, and performance with the main self-efficacy construct established by Bandura’s theory.

Personal factors like academic background, race, and gender may influence social interactions and bias access to sources of information that could help develop stronger efficacy beliefs for particular activities. If people experience unwelcome environments or stereotype threats, then their self-efficacy beliefs may decrease. This could lead people to be more likely to experience negative learning experiences that would ultimately have a negative influence on interest, choice of behavior, and performance in that particular activity (Lent et al., 1994).

SCCT is a useful framework to examine environmental variables that may be perceived as barriers or supports by students in particular learning experiences. These environmental variables could influence people’s career perceptions in a positive or negative way, modifying interest in their career-related activities and choice of behavior (Lent et al., 2000). SCCT refers to negative contextual influences as barriers. The way that people experience these barriers may affect their choice of activities as well as their behavior performing those activities. People that perceive themselves as being able to cope effectively with challenging tasks or a threatening environment would be less likely to define these factors as barriers. People’s perceptions of their ability to overcome barriers in their effort to attain their goals is defined by Lent et al. (2000) as coping efficacy. This concept is different from Bandura’s self-efficacy, with self-efficacy favoring the choice of
certain goals and actions, while coping efficacy could be determinant when adverse conditions complicate people’s performance and goal attainment. In terms of supports, SCCT identifies environmental variables that facilitate the development and pursuit of individual’s career choices and goals. These supports play an important role in the choice of actions that people make trying to attain their goals. Supports are considered as factors that could help the individual to overcome difficulties, and the simple absence of barriers or a threatening environment is not enough to be consider as a support.

The constructs in the SCCT are relevant to this study, giving context to students’ desire to become engineers, and how these students react to supports like tutoring and study groups; and students’ reactions to barriers such as poor understanding of math concepts or lack of time to balance their daily activities with their math work while they pursue their engineering degrees.
CHAPTER TWO
RESEARCH METHODS

2.1 Research Design

To thoroughly address this study’s research questions, a sequential explanatory mixed methods design (see Figure 2.1) was selected to lead this research (Creswell & Clark, 2011). According to Johnson, Onwuegbuzie, & Turner (2007), to conduct a mixed methods study both qualitative and quantitative data must be collected, analyzed, and mixed in a single study trying to answer a research question that could not be answered using a single methodology. The sequential explanatory mixed methods design was selected for this study to deepen our understanding of the effects of math SE on engineering students with poor math preparation performance, behavior, attitude, and persistence in college math courses. Although the quantitative phase was performed first, there was an emphasis on the qualitative phase of this mixed methods design. The qualitative phase of this study aimed to get a detailed explanation of the quantitative findings based on student’s interview responses about their experiences learning and performing math. To get a thorough description of students’ experiences taking college math courses, a constructivist grounded theory methodology was followed in the qualitative phase of this research to develop a theory based on the data (Charmaz, 2006). Following a mixed methods approach improved the quality of this study’s findings compared to only using a qualitative or quantitative methodology through weakness minimization (Onwuebuzie & Johnson, 2006), and a better understanding of the participants’ experiences in math courses and the
relationship between those experiences with their math SE levels was developed (Creswell & Clark, 2011).

Figure 2.1. Inputs and outcomes of the sequential explanatory mixed methods design

2.2 Participants

Participants for this study were selected according to the mathematics course in which they were enrolled during their first year at Clemson University. First-year students are placed into specific math level courses based on their performance on the Clemson Mathematics Placement Test (CMPT), a mandatory screening test used to determine students’ mathematics knowledge. Students wanting to major in science or engineering who have the lowest CMPT scores are placed in a Precalculus class (“Precalc”). Precalc is primarily an on-line course with two 75 minute classroom sessions each week with an instructor to answer students’ questions. Those scoring slightly higher on the CMPT but
who are not ready to take a full semester of Calculus as their first college math course are placed in a two-semester course combining Precalculus and Calculus; the first semester course in this series is “Long Calc”, and the following course is “Long Calc II”. Long Calc and Long Calc II together are the equivalent of Calculus I. Beginning in Long Calc allows student to review Precalculus material before learning Calculus at a slower pace, having two semesters rather than one to get through the material. Both Precalc and Long Calc are considered non college-level math courses and are designed to help students with poor mathematical preparation. These non-college-level math courses are slow paced and are graded as pass or fail; students completing one of these courses are considered ready to start a college-level Calculus course the following semester. Students from all majors enrolled in Precalc and Long Calc for the Spring and Fall semesters from 2014 to 2015 were stratified using their low performance in the CMPT as a criterion (Onwueguzie & Collins, 2007), aiming to collect information about students with poor math preparation in their first college math course.

A total of 408 students participated in the quantitative phase of this study: 101 students in three sections of Precalc, and 207 students in 5 sections of Long Calc in the Fall 2015 semester, and 20 students in one section of Precalc and 80 students in 3 sections of Long Calc in the Spring 2016 semester. Gender, race, and ethnicity of the students that completed the survey are presented to give some context to the type of students that usually start in non-college-level math courses in this university. For the 408 participants 75% self-identified as Caucasian, 18% as African-American, 3% as Latino, 2% as American Indian or Alaska Native, and 2% as Asian, Hispanic or other combination. Students enrolled in
these courses were 52% female and 48% males, and they were pursuing a variety different majors such as engineering, science, architecture, and business. There were more Precalc and Long Calc sections in the semesters that the qualitative phase was conducted, but only sections with instructors that agreed to distribute the survey during their class time were include in this study. Following a sequential data collection design (Onwuegbuzie & Collins, 2007), eleven engineering students were purposely selected from the previously stratified students after the quantitative analysis. Six of the eleven students that participated in the qualitative phase of the study were randomly selected from Precal and Long Calc courses in the Spring, Summer and Fall 2014 and Spring 2015 semesters. These six students were selected before starting the qualitative phase of this mixed methods study that lead to the theoretical sampling. Theoretical sampling is impossible to perform at the beginning of a grounded theory methodology due to the lack of data analysis and emerging theory to expand or compare it with new participants’ experiences (Strauss & Corbin, 1994). All students who volunteered were asked by email to participate in a 45-60 minute interview about their math experiences in high school and college. They were offered a $20 Amazon card as incentive if they agreed to volunteer for the study. Students that participated in the qualitative phase of this study were selected only from engineering majors, with the goal of reaching maximum variation within students’ math SE beliefs levels and competence/knowledge (Teddlie & Yu, 2007).
2.3 Data Sources

2.3.1 Quantitative Phase Data Sources

Each student’s math SE level was determined using both survey and interview responses. Survey responses were used to stratify students into clusters from high to low math SE and purposely select subsequent participants following theoretical sampling. Students’ interview responses, where they rated their math SE for different math related activities from 1 to 10 (e.g. How confident do you feel that you can solve your homework after being taught a difficult topic? Could you select your level of confidence in a scale between 1(not at all) and 10 (very confident)) were used as their math SE level for the mixed analysis and to be compared with students’ math competence/knowledge. The math SE average from the students’ interview responses rating their confidence performing math related activities was used for the mixed analysis to keep consistency with the values used for the mixed data analysis. Students that participated in the grounded theory before the math SE survey was used for theoretical sampling purposes did not complete the survey, and these six participants were missing this quantitative math SE measurement. The interview questions also provided the opportunity to understand the reasons behind students’ math SE levels performing different math activities which helped when analyzing the quantitative and qualititative data together.

This research used the Mathematic Self-Efficacy Survey (MSES) developed by Betz and Hackett (1983) to measure students’ math SE for the theoretical selection. The MSES consists of 52 items measuring three different math SE subscales: mathematics problem-solving (18 items), everyday mathematics tasks (18 items), and mathematics
courses (16 items), where students rate their level of confidence for each question on a scale ranging from no confidence at all (0) to complete confidence (10). This survey was selected for this study due to its high reliability in measuring math SE in prior studies from different authors in current literature (e.g. Brown & Burnham, 2012). Both the full-scale original survey and its subscales independently have been previously validated with coefficient alphas ranging from 0.90 to 0.96 (Brown & Burnham, 2012; Kranzler & Pajares, 1997; Lent et al., 1991; Pajares & Miller, 1995). Two MSES subscales were adapted to the context and population of this study. The problems used for mathematics problem-solving items were all replaced with problems similar to those used in the Precalc and Long Calc math courses, aiming to get a self-efficacy measurement that could be related to students’ performance in these specific courses (Bandura, 1986). The second adaptation was in the number and types of math and non-math courses in the mathematics courses subscale, changing some courses to match students’ curricula. This subscale ended up with only 14 items asking students their level of confidence to earn a B or a better grade in the course. Some of the everyday mathematics task subscale items were slightly updated to reflect current activities and facilitate the item interpretation by the students. This survey also collected information about the math courses that students took in high school aiming to determine students’ math preparation, and students’ demographic information such as gender and race. The final version of the MSES survey used in this research can be found in Appendix B.

All the instructors teaching the sections of Precalc and Long Calc during the Fall 2015 and Spring 2016 semesters were asked to distribute the MSES during class time.
Students from all majors in the sections that agreed to distribute the MSES completed the paper survey during class time, and the instructors collected the surveys and returned them back to the researcher for data analysis.

Students’ math competence/knowledge was estimated based on their performance on their college math course at the time of the interview. Students’ performance information was obtained from the online course software used to teach the course (ALEKS) for the Precalc students and the course test scores for the Long Calc students. The Assessment and LEarning in Knowledge Spaces (ALEKS) records the time that each student spends on every topic, and it shows the percentage and difficulty level of the topics that each student was able to solve and master. The information provided by ALEKS was used to calculate the Precalc students’ math competence/knowledge and compare the time that students spent working on their math assignments with the time they reported spending on math activities during their interview. ALEKS is not used in the Long Calc courses, so these students’ math competence/knowledge were estimated using a combination of their course grade and their CMPT score.

2.3.2 Qualitative Phase Data Sources

The data for the qualitative phase of this research was collected through semi-structured interviews, including questions about students’ reasons for choosing engineering, persistence in their desire to become engineers, math SE based on Bandura’s guide for constructing SE scales (Bandura, 2006), and social supports (Lent et al., 1994). The interview protocol was modified a couple of times during the qualitative data collection to expand and compare some students’ responses with additional participants.
following a grounded theory approach (Bryant & Charmaz, 2007). Some items were removed, while others were added or modified to get more information about the emerging codes and categories and to be able to develop a thorough theory. The final version of the interview protocol is presented in Appendix A.

The first six students that participated in the interviews were randomly selected from the previously stratified group of engineering students with poor math preparation, and the last five students were purposefully selected according to the quantitative phase results looking for maximum variation (see Figure 2.1). Each participant was selected after analyzing and coding the data from the previous participant, and the theoretical selection was performed based on the emerging codes and categories from previous participants. After selecting the appropriate profile for the next grounded theory participant, students matching the required profile were contacted by e-mail to ask for volunteers. The e-mail invitation briefly described the study and invited the students to volunteer for a 45-60 minute interview. Several students were contacted by email and additional emails were sent to follow-up if they did not answer the first email. Five students responded to the e-mail invitations and interviews were conducted with different students every 2 or 3 weeks between the Fall 2015 and Spring 2016 semesters. Interviews were audio recorded and transcribed. During the interview, students were asked to rate their self-efficacy on a scale of 1-10 (similar to Bandura’s approach to constructing self-efficacy scales) for specific math skills, such as solving word problems and finding errors in their calculations. The rest of the interview questions were open-ended, with follow-up questions that were used depending on the student’s responses.
Following a grounded theory method, the first interview was coded and analyzed before conducting the next interview (Bryant & Charmaz, 2007); and this process continued for all subsequent interviews. The codes, memos and responses from the first interview analysis were used to modify the interview protocol between participants according to emerging themes and missing information aiming to develop a thorough theory. Preliminary findings of this qualitative analysis were used together with the quantitative results to inform the theoretical sampling. This theoretical sampling and refining of the interview protocol were part of a cycle for selecting the most appropriate participant (see Figure 2.1).

2.3.3 Grounded Theory Data Collection Evolution

According to the findings of the data analysis from the first participants and following a grounded theory approach (Charmaz, 2008a), the interview protocol was refined between student interviews based on what remained unknown or unclear. Some questions were added to the changing interview protocol, while others were removed or modified aiming to test and expand the emerging theory. The most significant modifications to the interview protocol during the qualitative collection were GT protocol change 1 after the first three participants and GT protocol change 2 after the sixth participant (see Figure 2.2).
The data analysis and the constant comparison of emerging codes and categories led to the following grounded theory data collection adaptations (see Figure 2.2):

**Grounded Theory Protocol Change 1:** Some questions about students’ performance and final grades were added to build a better understanding of students’ precollege math preparation. Additionally, two questions about students’ mindset of learning math and people’s intelligence were included, aiming to gain a better perspective of students’ beliefs about math courses in general and what types of students could learn good math abilities. After the third student’s interview was analyzed, a math test with 9 items related to Precalculus topics was designed to be shown to the students. This question about students’ confidence solving the test correctly was included in the interview protocol to analyze students Math SE at the moment that they were facing some math problems, and not just talking about what they think about their math competence/knowledge in general. The remaining interview participants rated their level of confidence solving all the math problems correctly as part of the interview.
After analyzing the data from the first group of participants, the emerging codes were very raw, and theory was not well developed to start using theoretical sampling to select the following participants of the study, so they were randomly selected from the Pracalc and Long Calc courses. Although the participant selection was still random for the first two groups of participants, there was an effort to try to target the e-mail invitations to non-African-American students. This effort to find a different type of student was because all participants that had volunteered up to this point were African-American students, and some diversity within students’ race was desirable to create a theory that could represent a more diverse community of students.

**Grounded Theory Protocol Change 2:** After collecting and analyzing data from the first six participants, some codes and categories were established well enough to be tested and lead the theoretical sampling to keep developing the emerging theory in following interviews. The MSES results were used to classify students’ math SE in different levels and be able to select the most appropriate participant to keep developing the emerging theory. A couple of questions were added to the interview protocol, these new questions were aiming to understand more about the evolution of students’ math SE from high school to college, and determine what activities or experiences could modify engineering students’ perception of their math competence/knowledge in college math courses. This math SE evolution was something that other students mentioned before, and more information about this math SE change was needed to complement the emerging theory and answer this study’s research questions. The remaining interview participants were also asked about their feelings about their math abilities compared to their college classmates. At this point the number of female
and male participants was equilibrated, and the issue of having only African-American participants was resolved with the participation of two Caucasian students in the second group of participants.

**Grounded Theory Protocol Change 3:** After interviewing and analyzing nine grounded theory participants, some categories started to emerge. The goal in selecting the next group of participants was to test and consolidate these categories, asking different students similar questions and trying to check if they reacted in the same way that other participants did when they faced similar experiences taking math college courses. One of the main categories that was tested and expanded with the following participants was looking at how the engineering students adjusted their high math SE beliefs coming from high school to a lower level once they faced some struggles in college math courses. Interview participants up to this point usually changed their approach to taking college math courses after failing their first math course at college, and some questions about how this failing experience affected their behaviors and attitudes in math classes was added to the interview protocol. Additionally, a couple of questions asking students if they were feeling anxious performing math related activities were added to the interview protocol, trying to understand how struggling in math courses could affect their confidence to perform in more advanced math courses.

Some clusters with matched and mismatched math SE and competence/knowledge were lacking enough participants to determine the general behavior and attitudes of the type of students that conformed each group. Hence, the goal of theoretical sampling for the selection of the following participants was to find the right student that could help to
understand how students behave in their college math courses depending on their math SE and math competence/knowledge relationship. Despite finding some engineering students that fit in one of the matched and mismatched math SE and competence/knowledge clusters, it was not possible to recruit the appropriate participant to keep developing the theory, especially for some clusters with few possible participants to select from. This issue was a problem during theoretical sampling, and because of the poor response to the e-mail invitation from certain students, some clusters were lacking enough participants and data to determine this type of students’ general behaviors and attitudes in college math courses.

2.4 Data Analysis

2.4.1 Quantitative Phase Data Analysis

The data collected with the MSES was analyzed using descriptive statistics and cluster analysis to classify student’s math SE level using the statistical software R (Team, 2012). A K-means cluster analysis was conducted to classify students in three homogenous subgroups based on their math SE levels (Maechler, Rousseeuw, Struyf, Hubert, & Hornik, 2015) for each semester that the MSES was used to collect data. The three clusters were identified with the K-means cluster analysis, classifying students’ math SE beliefs according to their group mean as low, medium and high. These clusters were used to purposefully select individuals with the appropriate characteristics for the qualitative phase to get a maximum variation within math SE beliefs. Students’ math competence/knowledge was classified as high or low according to each course average.
2.4.2 Qualitative Phase Data Analysis

The qualitative phase of this study used a constructivist grounded theory approach (Bryant & Charmaz, 2007). This particular methodology was selected to develop an evidence-based theory about academic behaviors of engineering students with poor math preparation math SE, which is missing in the broad math SE literature. Although there are a few studies analyzing the relationship between students attitudes and behavior in math courses according their math SE (Brown & Burnham, 2012; Zeldin, Britner, & Pajares, 2008; Zeldin & Pajares, 2000), there is no current literature focusing on the effects that math SE could have on engineering students with poor math preparation behavior and performance in college math courses. The lack of literature about engineering students with poor math preparation math SE lead to the selection of a constructivist grounded theory approach to analyze the qualitative data. Following a constructivist grounded theory approach enabled the researcher to use a framework and some related literature to code and analyze the qualitative data, aiming to develop a theory grounded in this data analysis (Charmaz, 2000).

Following a constructivist grounded theory approach, the qualitative data was initially coded line-by-line using open coding (Charmaz, 2006). Codes emerged directly from the data, and they were named using gerunds and participants’ words (in vivo coding) during the interview aiming to develop a theory that could accurately represent students’ experiences and actions in their college math courses (Bryant & Charmaz, 2007). This coding philosophy facilitated the theoretical interpretation of the data based on what was reported by the participants. The initial codes were constantly analyzed and compared
between participants. During this analysis process, memos were written as notes that described the researcher’s interpretation of the emerging codes (Charmaz, 2007). These memos helped the researcher to develop categories based in the constant comparison of codes, memos, and data, letting the categories emerge as the more representative actions of engineering students with poor math preparation in college math courses. Findings of this phase are presented as codes, categories and diagrams of connections between categories. After a constant comparison of codes, memos, categories, and data of different students, the final categories became the core of a theory grounded in the data that described math SE perceptions of engineering students with poor math preparation, and how their self-efficacy beliefs are related to their behavior and attitudes in college math classes.

2.4.3 Mixed Phase Data Analysis

The mixing between the quantitative and the qualitative phases occurred in two different places in this research. The first mixing phase took place during the data collection. During this mixing phase the quantitative results informed the participant selection for the qualitative phase to perform theoretical sampling accurately, using the MSES results to purposely select the most adequate characteristics of the subsequent participants for the qualitative phase (Sandelowski, Voils, & Knafl, 2009).

Additionally, after finalizing both quantitative and qualitative phases, the findings and data of these two phases were analyzed together aiming to expand our understanding of the possible influences of math SE on engineering students and answer the research questions. This final analysis thoroughly integrated the two methods, helping the researcher
consolidate, compare, and integrate in a coherent whole both qualitative and quantitative findings (Onwuegbuzie & Combs, 2010). To accomplish this, survey data (clusters) and interview data (categories, codes, diagrams) analysis were compared side by side for each participant, aiming to triangulate the data to compare and expand the findings of each phase (Moran-Ellis, 2006).

This second mixing phase helped the researcher to classify students in different groups depending on their math SE beliefs and math competence/knowledge relationship. Students were classified in groups where they showed having a gap between their math SE beliefs and their math competence knowledge or where they support their math SE beliefs with a similar math competence/knowledge. If students showed a gap larger than 1 point between their math SE beliefs assessment (between 1 and 10) and their math competence/knowledge assessment (between (1 and 100) divided by 10), then these students were considered having a mismatch between these two factors; if the gap between these two factors was lower than 1 point, then these students were considered having a match between their math SE and competence/knowledge. Classifying students in groups with a mismatched and a matched math SE beliefs and math competence/knowledge was useful to determine engineering students’ behaviors and attitudes in math courses depending on how well aligned these two factors were for each student. Comparing students’ behaviors and attitudes in their math college courses helped the theory development and was necessary to answer this study research questions thoroughly.
2.5 Quality Considerations

2.5.1 Quantitative Phase Quality Considerations

The adapted version of the MSES was validated using Cronbach’s alpha values to evaluate the internal consistency reliability of the survey items for this specific population (Thorndike & Thorndike-Christ, 2010). All MSES constructs were expected to have a Cronbach’s alpha value above 0.7 (Nunnally & Bernstein, 1994), showing that they are measuring theoretical similar concepts. Although this survey’s validity has been tested before, content and face validity were evaluated with qualitative experts and math professors at Clemson, making sure the items were understandable for students and were all measuring the same construct in a thorough way (Creswell, 2009).

2.5.2 Qualitative Phase Quality Considerations

According to Johnson (1997), there are 5 types of validity that need to be considered to validate qualitative studies. These types of validity are called descriptive validity, interpretive validity, theoretical validity, internal validity, and external validity. **Descriptive validity** refers to the accuracy of the data reported by the researcher, and how close this data is to what really happened. To address this descriptive validity, an additional person was present in the interviews to take notes and help triangulate and discuss the data after the interviews.

**Interpretive validity** refers to the degree that data interpretation really reflects participants’ beliefs, experiences, and feelings about the phenomenon. Participant feedback is key in this type of validity. A summary of the conclusions of each participant interview were sent by e-mail to the interviewee after the data analysis. The participants were asked
to provide feedback about the accuracy of the conclusions and the researcher interpretation of their experiences taking college math course, and they had the chance to modify anything they thought was not stated during the interview. Four participants responded to the request for feedback. Three of these participants completely agreed with the interpretation and description of their experiences taking math courses in college, and the comments and edits of the one participant that suggested some minor edits in his summary of conclusions were included in the final conclusions of this research. The rest of the students did not answer the e-mail, despite sending them reminders asking for their feedback.

Emerging codes were constantly tested with other participants to do member checking, and with other qualitative researchers to discuss different points of view about the data analysis. To remain close to the data and enhance this descriptive validity, verbatim (participants’ direct quotations) were used during the coding process.

**Theoretical validity** is reached according to the degree that qualitative findings have a theoretical explanation grounded in the data, making this theory credible. The developed theory should be able to clearly explain the details of the phenomenon in general, and not just facts about the study participants. The grounded theory methodology was a perfect fit in the developing of such theory, using theoretical sampling to purposefully select different type of participants that enriched and complemented the emerging theory.

**Internal validity** refers to the degree that a researcher is able to determine the causality of an observed relationship. Although this research provided rich descriptions of
the relations of engineering students’ behaviors and attitudes with their math SE and math competence/knowledge, findings of this research are not adequate to determine causality of the expected findings due to the small number of participants. Lastly, external validity refers to the generalization of the study findings. For readers to address external validity, this research described the study sample in detail and clearly communicated what findings can be applicable to other populations if there are similarities between this study sample and the intended target population.

2.5.3 Mixed Phase Quality Considerations

This study used the Onwuebuzie & Johnson legitimation framework (2006) for mixed methods quality considerations. For this framework, nine legitimation types are considered to improve the quality of mixed methods studies including: sample integration, inside-outside, weakness minimization, sequential, conversion, paradigmatic mixing, commensurability, multiple validities, and political. Only certain legitimation types were considered appropriate to the mixing phase of this study; the other validation types were not considered. Sample integration refers to the importance of the relationship between the quantitative and qualitative samples. During the mixing phase, the sample for the qualitative phase was selected from a subset of the quantitative sample, using the quantitative results to inform the theoretical sampling for the qualitative phase. This sampling method followed an explanatory sequential design, aiming to construct inferences that could represent more appropriately the whole sample. Inside-outside legitimation refers to the extent to which the researcher understands the insider’s (participant’s) and observer’s (researcher’s) experiences. Member checking and additional
researcher reviews were performed to ensure the inclusion of both the insider and outsider perspectives while analyzing the participants’ experiences. Weakness minimization means that the possible weaknesses of one approach could be compensated by a different approach. This type of legitimization was considered from the beginning of the study, using the qualitative phase to expand and generate a thorough theory based in the quantitative results. Students’ behaviors and attitudes and their relation to students’ math SE level were described using the richness of the data collected in the qualitative phase, and complementing these findings with quantitative results that helped to develop a thorough theory. Because of this explanatory sequential design (Creswell & Clark, 2011), it is not possible to interchange the order of the quantitative and qualitative phases, but all the inferences equally considered both phases’ findings to make the final conclusions. There was not data conversion (quantitizing nor qualitizing (Sandelowski et al., 2009)) to analyze the whole data, but there was a constant side by side data comparison before making inferences. Multiple validities were used aiming to enhance the quality of the final outcome, performing individual quantitative and qualitative quality assessments prior the final integration of the results.
CHAPTER THREE

RESULTS AND FINDINGS

3.1 Quantitative Results

3.1.1 MSES Validation

Cronbach’s alpha ($\alpha$) was calculated for each construct from the MSES to assess the internal consistency reliability of the items. All the survey constructs were tested for each semester that the survey was deployed, resulting in a Cronbach’s $\alpha$ value for the three survey constructs for the Fall 2015 semester and another three values for the Spring 2016 semester (see table 3.1).

Table 3.1: Number of items and Cronbach’s $\alpha$ values of the items of each construct on the MSES for the Fall 2015 and Spring 2016 semesters.

<table>
<thead>
<tr>
<th>MSES</th>
<th>Construct</th>
<th>Cronbach’s $\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fall 2015</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Math Activities (18)</td>
<td></td>
<td>0.91</td>
</tr>
<tr>
<td>Math Courses (14)</td>
<td></td>
<td>0.83</td>
</tr>
<tr>
<td>Math Problems (18)</td>
<td></td>
<td>0.90</td>
</tr>
<tr>
<td><strong>Spring 2016</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Math Activities (18)</td>
<td></td>
<td>0.69</td>
</tr>
<tr>
<td>Math Courses (14)</td>
<td></td>
<td>0.80</td>
</tr>
<tr>
<td>Math Problems (18)</td>
<td></td>
<td>0.90</td>
</tr>
</tbody>
</table>

(# = numbers of items on each construct.)

All constructs showed a good internal consistency reliability in the Fall 2015 survey, with Cronbach’s $\alpha$ values above 0.8. The only construct that was slightly below the acceptable cutoff of 0.7 (Trochim & Donnelly, 2007) was the math activities construct for the Spring 2016 semester, with an $\alpha = 0.69$. Although the math activities construct had a low Cronbach’s $\alpha$ value for the Spring 2016 semester, this construct showed good internal consistency reliability in the Fall 2015 with $\alpha = 0.91$. This math activities construct was kept for the data analysis due to the low sample in the Spring 2016 semester ($n = 23$), which is less reliable than the Fall 2015 Cronbach’s $\alpha$ value for the same construct using a bigger
sample (n = 89) (Onwuegbuzie & Leech, 2007). The rest of the constructs in the Spring 2016 semester showed Cronbach’s α values above 0.8, meaning that the items within each construct are strongly correlated (Nunnally & Bernstein, 1994).

3.1.2 Participants’ Math Competence/Knowledge

The students’ math competence knowledge was estimated based on their performance on the math course that they were taking at the time of the interview. Some grades were not final due to the time of the semester that the interview was conducted. Table 3.2 displays students’ grades for all the math courses that they have taken in college and their CMPT scores.

Table 3.2: Students’ grades in college math courses.

<table>
<thead>
<tr>
<th>Participants</th>
<th>CMPT</th>
<th>1st Math Course</th>
<th>2nd Math Course</th>
<th>3rd Math Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>P Spring 2014</td>
<td>Not Found</td>
<td>(P) 56</td>
<td>(P) 81</td>
<td>N/A</td>
</tr>
<tr>
<td>L Summer 2014</td>
<td>67</td>
<td>(L) Pass</td>
<td>(L2) 91</td>
<td>(C2) 87</td>
</tr>
<tr>
<td>P Fall 2014 (1 of 2)</td>
<td>42</td>
<td>(P) 15</td>
<td>(P) Fail</td>
<td>N/A</td>
</tr>
<tr>
<td>P Fall 2014 (2 of 2)</td>
<td>48</td>
<td>(P) 29</td>
<td>(C) Fail</td>
<td>(C) Fail</td>
</tr>
<tr>
<td>L Spring 2015</td>
<td>69</td>
<td>(L) 67</td>
<td>(L) 73</td>
<td>(C2) 39</td>
</tr>
<tr>
<td>P Spring 2015</td>
<td>82</td>
<td>(C) Fail</td>
<td>(P) 67</td>
<td>(C) 70</td>
</tr>
<tr>
<td>L Fall 2015</td>
<td>70</td>
<td>(L) 85</td>
<td>(L2) 73</td>
<td>N/A</td>
</tr>
<tr>
<td>L Spring 2016 (1 of 3)</td>
<td>76</td>
<td>(L) 29</td>
<td>(L) 66</td>
<td>N/A</td>
</tr>
<tr>
<td>P Spring 2016</td>
<td>71</td>
<td>(L) Fail</td>
<td>(P) 83</td>
<td>N/A</td>
</tr>
<tr>
<td>L Spring 2016 (2 of 3)</td>
<td>83</td>
<td>(L) 64</td>
<td>(L) 65</td>
<td>N/A</td>
</tr>
<tr>
<td>L Spring 2016 (3 of 3)</td>
<td>68</td>
<td>(L) 58</td>
<td>(L) 82</td>
<td>N/A</td>
</tr>
</tbody>
</table>

P = Precal, L = Long Calc, L2 = Long Calc II, C = Calculus I, C2 = Calculus II. The lowest passing grade is 70 for all these college math courses. Pass and Fail grades were assigned to courses were only passing or failing records were available. The grade of the math course that students were taking at the moment of the interview is bolded.

Only the grade of the math course that students were taking at the moment of the interview was used as their math competence/knowledge, and this math competence/knowledge estimation was compared with their math SE beliefs for the mixed
analysis of the data. Additional math course grades helped to determine students’ performance and behavior in prior and following math courses, which lead to a better understanding of student’s experiences of taking college math courses.

### 3.1.3 Participants’ Math SE

Students’ math SE beliefs were assessed using the interview questions focused on rating their level of confidence performing different math activities. The average of the participants’ interview responses rating their math SE was used to compare students’ math competence/knowledge with their math SE. All students have a math SE average from their interview responses (see Table 3.3), and the number of questions that students answered to get that math SE average changed while the qualitative phase of the study was evolving following a grounded theory methodology.

Starting with the sixth participant, students answered the MSES to classify their math SE beliefs before the interview. Results of the MSES were used to purposely select the most appropriate participant to complement and further develop the emerging theory. Only the last five participants answered the MSES, and these survey averages were used for theoretical selection purpose only (see Table 3.3). The average of the interview answers rating students’ math SE was used to describe students’ choice of behavior and attitudes and determine how well students’ math SE beliefs were representing their actual math competence/knowledge during the mixed data analysis.
Table 3.3: Students’ math SE averages for their interview and MSES responses.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Math SE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Interview</td>
<td>MSES</td>
</tr>
<tr>
<td>P Spring 2014</td>
<td>6.6</td>
<td>NA</td>
</tr>
<tr>
<td>L Summer 2014</td>
<td>7</td>
<td>NA</td>
</tr>
<tr>
<td>P Fall 2014 (1 of 2)</td>
<td>7.6</td>
<td>NA</td>
</tr>
<tr>
<td>P Fall 2014 (2 of 2)</td>
<td>8</td>
<td>NA</td>
</tr>
<tr>
<td>L Spring 2015</td>
<td>6.2</td>
<td>NA</td>
</tr>
<tr>
<td>P Spring 2015</td>
<td>6.8</td>
<td>NA</td>
</tr>
<tr>
<td>L Fall 2015</td>
<td>7</td>
<td>5.8</td>
</tr>
<tr>
<td>L Spring 2016 (1 of 3)</td>
<td>6.5</td>
<td>7.9</td>
</tr>
<tr>
<td>P Spring 2016</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>L Spring 2016 (2 of 3)</td>
<td>6.9</td>
<td>8.8</td>
</tr>
<tr>
<td>L Spring 2016 (3 of 3)</td>
<td>7.8</td>
<td>8.6</td>
</tr>
</tbody>
</table>

Math SE average was rated from 1 to 10. The first 6 participants did not take the MSES.

Aiming to develop a thorough theory that could represent students with different math SE levels and how they behave in their college math courses, a K-means cluster analysis was conducted to group students in three different clusters according to their math SE. Students’ MSES responses were separated into three groups for each of the two semesters that the MSES was distributed and analyzed (see Figure 3.1). These groups were called medium low, medium high, and high math SE groups, and theoretical sampling was performed aiming to reach maximum variation within these three different levels of math SE (Teddlie & Yu, 2007). There was not a low math SE group because the lowest math SE beliefs measured by the MSES for these engineering students were not low, with a mean of 6.6, showing that engineering students with poor math preparation are likely to report relatively high math SE during their first college math course. Following the theoretical
selection guidelines (Corbin & Strauss, 2008), students were selected from each of the three math SE groups in order to complement and test the emerging theory. One student was selected from the medium low math SE group for the Fall 2015 semester, and two students were selected from both the medium high and high SE groups for the Spring 2016 semester (see table 3.4).

Table 3.4: Means of the math SE averages reported by the Fall 2015 and Spring 2016 semesters separated in 3 clusters.

<table>
<thead>
<tr>
<th>Clusters</th>
<th>Mean (MSES)</th>
<th>Students</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2015</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 → Medium Low</td>
<td>6.6</td>
<td>24</td>
<td>*</td>
</tr>
<tr>
<td>2 → Medium High</td>
<td>8</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>3 → High</td>
<td>9.2</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Spring 2016</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 → Medium Low</td>
<td>6.3</td>
<td>6</td>
<td>**</td>
</tr>
<tr>
<td>2 → Medium High</td>
<td>8</td>
<td>13</td>
<td>**</td>
</tr>
<tr>
<td>3 → High</td>
<td>9.3</td>
<td>5</td>
<td>**</td>
</tr>
</tbody>
</table>

* Number of participants selected from this cluster

Figure 3.1: Cluster distribution for the Fall 2015 and Spring 2016 semester using the mean of each cluster.
A couple of additional students were selected to participate in this research due to their math SE level and the need complement and test the emerging theory. However, they did not reply to the e-mail invitation, which lead to the current sample for this study.

3.2 Qualitative Findings

3.2.1 Participants Descriptions

Summaries of each of the eleven (see Table 3.5) participants’ interviews were developed after analyzing all of the qualitative data. These summaries describe students’ behavior during their first experiences taking college math courses, classifying their experiences in sections that described how they reacted to different situations, and their math SE and competence/knowledge levels. An example of one of these summaries is presented below, describing the 11th participant’s experiences taking Long Calc in the Spring 2016 semester. The rest of the participants’ interview summaries are reported in Appendix C.

Table 3.5: Participants’ math SE and math competence/knowledge.

<table>
<thead>
<tr>
<th>Interview Order</th>
<th>Participants</th>
<th>Math SE</th>
<th>Math Competence/Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P Spring 2014</td>
<td>6.6</td>
<td>81</td>
</tr>
<tr>
<td>2</td>
<td>L Summer 2014</td>
<td>7</td>
<td>91</td>
</tr>
<tr>
<td>3</td>
<td>P Fall 2014 (1 of 2)</td>
<td>7.6</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>P Fall 2014 (2 of 2)</td>
<td>8</td>
<td>29</td>
</tr>
<tr>
<td>5</td>
<td>L Spring 2015</td>
<td>6.2</td>
<td>73</td>
</tr>
<tr>
<td>6</td>
<td>P Spring 2015</td>
<td>6.8</td>
<td>67</td>
</tr>
<tr>
<td>7</td>
<td>L Fall 2015</td>
<td>7</td>
<td>85</td>
</tr>
<tr>
<td>8</td>
<td>L Spring 2016 (1 of 3)</td>
<td>6.5</td>
<td>66</td>
</tr>
<tr>
<td>9</td>
<td>P Spring 2016</td>
<td>9</td>
<td>83</td>
</tr>
<tr>
<td>10</td>
<td>L Spring 2016 (2 of 3)</td>
<td>6.9</td>
<td>65</td>
</tr>
<tr>
<td>11</td>
<td>L Spring 2016 (3 of 3)</td>
<td>7.8</td>
<td>82</td>
</tr>
</tbody>
</table>
3.2.1.1 Long Calc Spring 2016 Student (3 of 3)

**Student description:** This is a white male student pursuing a degree in environmental engineering. He reported an overall math SE of 7.8 (out of 10) while he was taking Long Calc for the second time. He was interested in engineering because his father is an engineer, and he wanted to maintain a better environment:

Well, um, my dad is an engineer, he is a chemical engineer, and one thing I always thought about was like, oh I can do something like my dad does. Later I learned that the reason I want to be an engineer is that I'm interested in the sustainability aspect of engineering.

This student considers math as a challenging topic that demands a lot of practice and hard work: “I think they [college math courses] are challenging and it takes a lot of practice to learn how to do, um, the math courses correctly.” And he is aware that his college math courses will need more effort and practice time than his high school math courses did. He also believes that certain people have a natural gift for learning math easier than others, but he thinks that anyone could learn to solve challenging math problems if they put in enough effort and practice. He was confident about his math competence/knowledge, but he does not see himself as mathematically gifted: “Um, I feel fairly capable, not, you know, the tip top capable, but I feel like I'm not bad at it. I would feel a little bit above average in that [current math course].”

**High school experiences:** He took several math courses in high school, and he got to college with some college-level math experience after taking a Calculus course his senior year. He
felt comfortable and confident in his math courses in high school, and he did perform well in all of them:

I took, um, Precalculus and Calculus, Geometry, and Trigonometry also, and Prealgebra, and Algebra also. Those courses I did alright, um, especially since one led into the other. I did alright through the first few and then Calculus was fine for me.

He liked the way that math was taught in his high school, giving students the opportunity to learn the basic math concepts and then scaffolding the course level to prepare students to take more advanced math courses. He took Calculus his senior year and he did really well, making him believe that he was ready to take a college-level math course after finishing his high school preparation: “I did [take math my senior year], yes Calculus. I think I ended that class with a high B or a low A grade, around a 90 I would say.”

**College math experiences:** This student was taking Long Calc for the second time at the time of the interview. The main reason for failing his first Long Calc attempt was that he got overconfident thinking that he already knew the material, and he did not put forth enough effort and practice to perform better:

Well the first time [taking Long Calc], I was under the assumption that, ‘Oh I know this stuff, I don't have to study as much as thought I did,’ and I didn’t put as much practice as you need to do it.

He feels that math college courses are different from high school math courses, but mostly because the pace in college math courses is faster and he is not used to covering that many topics in one class: “Since I'm in college [the pace] is a lot faster and a lot quicker pace,
um... but it's been alright I would say.” Although he is confident about his basic math competence/knowledge, he thinks that college math courses could be challenging because they look to expand your basic math knowledge to be able to learn advanced math topics that he did not learn in high school: “Since getting to college, [math] is a lot more in depth, and taking what you know as the basics and carrying that forward.”

Although he was performing better the second time that he was taking Long Calc, his perception about college math courses was the same; he was still thinking that college-level math courses were going to be challenging and he would need to set aside a lot of practice time to be able to complete all the math courses required by his major: “[Math] is still, you know, difficult, but it is easier when I have a lot of time to go over the problems as we do in class.” He worked hard to complete his Long Calc course the second time he took it, solving math assignments and checking his notes to be sure that he understands everything clearly: “I would say around 4 or 5 [hours working on math] because that would include homework, and also studying, and going over the material that I did not finish in class.”

Math SE: He reported a high math SE of 7.8 (out of 10) during the interview. This math SE was lower than the math SE he reported in his survey answers, which was an average of 8.6 (see Table 3.6). His math SE survey responses about performing well in different math courses was very close to his math SE interview average, but his confidence in performing math in his daily activities and solving math problems were higher, with a 8.4 and a 9.6 respectively (see Table 3.6). This student mentioned being aware that he was
using 8 as his level of confidence for most of the interview questions. He reported considering 8 a high value, showing great confidence in his overall math abilities.

Table 3.6: Long Calc Spring 2016 student (3 of 3) math SE.

<table>
<thead>
<tr>
<th></th>
<th>Math SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interview</td>
<td>7.8</td>
</tr>
<tr>
<td>Survey</td>
<td></td>
</tr>
<tr>
<td>Math activities</td>
<td>8.4</td>
</tr>
<tr>
<td>Math courses</td>
<td>7.9</td>
</tr>
<tr>
<td>Math problems</td>
<td>9.6</td>
</tr>
<tr>
<td>Average</td>
<td>8.6</td>
</tr>
</tbody>
</table>

This student’s good performance in high school math courses helped him to develop a high math SE, and he was confident that his math competence/knowledge would be good enough to learn the most challenging topics in his college math courses. Despite showing a high math SE, he struggled to completely understand some difficult college math topics like integrals, and that made him feel less confident about his math competence/knowledge: “I would say in high school I was a 9 or a 10 [math SE], but coming to college it dropped a little, it probably dropped to a 7 or 8.” Although this student’s math SE decreased after facing some struggles with college math courses, he stated that seeking help and taking advantage of the resources available to him to address his doubts, and having more practice time would help him to increase his confidence in his math abilities: “I would say, um, outside help, going to study sessions, and also doing extra practice problems would increase my own confidence in the class.” He was confident about his math abilities that he would need to complete all the math courses required by his engineering major, and he was planning on taking Long Calc II during the summer: “I'm taking that class [Long Calc II] over the summer, and that would allow me to have more time to focus on that specific class and study a little bit more.”
He reported similar math SE for most of the different math activities described in the interview questions. His lowest math SE value was reported when he was asked about solving homework after being taught a new difficult math topic, and he stated that this low math SE was mostly because he would need some practice before feeling more comfortable solving math problems about a new topic:

I would say I feel around probably with a new topic, um, 6.5. Because I wouldn't have much experience with the new topic. I feel like my confidence will be kind of low initially, but as we keep learning, I feel like my confidence level would get higher and higher.

He was confident about his abilities to solve math problems even if he struggles to solve them the first time, making emphasis that he can solve most of his math assignments after having some practice time:

Well I feel that my confidence level would be about the same because even though I didn’t get it [math problem] right the first time, um, I can take a different approach and do it again. I don’t think my confidence would be too detrimental from that.

Math competence/knowledge: This student reported having a good performance in high school courses, scoring a high B in his Calculus course. Although he performed well in his Calculus high school course, he did not score high enough on his CMPT to start in Calculus I in college. He took Long Calc his first semester in college and he failed with a final grade of 58 (see Table 3.7). After failing his first Long Calc course, he decided to take it again the following semester. He was performing better than his prior performance in his first college math course (see Table 3.7) at the time of the interview. He scored a 91 on the first
exam and a 73 the second exam. This student’s performance suggests a good basic math competence/knowledge, and that he was on track to completing the course successfully.

He reported using a problem solving strategy similar to what has been described for novice students with poor experience solving math problems (Larkin, McDermott, Simon, & Simon, 1980). He usually tries to identify the surface variables of a problem, and then he tries to solve the problem isolating that information and plugging those variables into equations:

I start with determining what needs to be solved for. Um, I would like to go to the side of that problem, and write everything out first, and see it on paper, and see if it makes sense, and then go from there.

Although he felt that Long Calc was a challenging course, he considered his math competence/knowledge to be a good fit for this course. He felt comfortable with the class pace and having enough time to solve his assignments:

I feel that I'm placed in the right course. Is not as rushed as other courses are such as Calculus I. I feel like being placed in Long Calc allows me to understand the concepts a little bit more, but it still not the easiest math at the same time. I feel like it fits very well.

Table 3.7: Long Calc Spring 2016 student (3 of 3) performance in his college math courses.

<table>
<thead>
<tr>
<th>Term</th>
<th>Course</th>
<th>Course average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2015</td>
<td>Math 1040 (Long Calc)</td>
<td>58</td>
</tr>
<tr>
<td>Spring 2016</td>
<td>Math 1040 (Long Calc)</td>
<td>82 (not final)</td>
</tr>
</tbody>
</table>

Academic behavior: This student reported a high math SE coming from high school and he got overconfident about his math competence/knowledge in his first college math
course. This overconfidence about his math competence/knowledge made him believe that he would pass the course without any extra effort, and he did not practice enough to perform well on his tests:

I'm doing more practice problems, really being involved in the class such as working the problems in the outside ‘cause before I didn’t really do that, and I didn’t really do the homework, and the homework is a big part of the practice. Um... So this time I feel that I'm able to time manage and plan things up better compare to last time.

After failing the first time he took Long Calc, he changed his approach when he took the same course the following semester. He realized that he would need to work harder and put more effort in practicing the course material to be able to perform well on the tests and pass the course. His failing experience had a positive impact on his work ethic: “Since I'm taking the class again, I'm putting a lot more effort into it, a lot more practice, um, and like really being involved with the course.” This student adjusted his high math SE to a lower level after his failing experience. His math SE was more aligned with his basic math competence/knowledge the second time that he took Long Calc, but it was still high enough to make this student believe that his math competence/knowledge was good enough to complete all the math courses required by his major if he continues working hard and spends extra time working on his math assignments: “Well I really would like to be an engineer and I realized that, Oh I'm going to need to put a lot more effort into this [college math courses].”
After his falling experience in his first college math course this student was more likely to work individually, but to seek help when he struggled with certain topics:

Usually I would go back through the homework assignments that we have done. And also there are extra assignments that we don’t get to in class, so I’ll just go back and practice those, and if I have a problem with one, then I'll go to my teacher and say can you help me with this and she will guide me through it.

He did not mention going to math tutoring, and he only asked his friends for help if he was struggling with a math topic in class and he wanted to compare his answer to a friend’s work. If his friends are not able to help him to solve his problems, he usually asked the professor for a deeper explanation.

Well I would try to see if anyone else in my class understands it to get helped that way. But if they can’t help me or they don’t understand it, I’ll go either in class or before class to my instructor and get helped that way.

He considered struggles in his math course as a way to increase his math abilities, and realized which topics he would need more practice on in order to understand them:

I would probably go back and figure out why I got it [math problem] wrong, like what I didn’t understand it in class. Um, if I didn’t study that material enough, I wouldn’t wanna blow it off, I would wanna get back down and look at the real in deep part of it.

His high math SE helped him to stayed motivated and made him believed that he can perform well in future college math courses, but he acknowledged that he sometimes gets overconfident and does not put enough effort into practicing math: “Even though I do
study, I do some studying more than other times and I think I need to keep consistency in that, so I stay up to it on everything.” He does not normally feel stressed or anxious working math, and he is confident that he can perform well on math tests if he spent some time practicing the new topics that he had learned during the course:

I usually don't feel too stressed when I'm working on math problems. I feel more stressed when I feel that there is a lot of new concepts being introduced at one time, but if the concepts keep building on the other, I feel like I won’t be as stressed or stressed at all.

**Math and engineering relationship:** He relates engineering with math abilities; and he thinks that his abilities to perform math are good, and that helped him to select his major:

I'm OK at math, I like having one definitive answer at the end and... lots of math involves... you know lots of engineering involves math so that's also a reason to follow the engineering path.

He feels confident that his basic math abilities are good enough to be able to solve the math involved in engineering problems that he may face in his major.

### 3.2.2 Defining Students’ Behaviors and Attitudes

After a constant comparison of the data, memos, and codes from the eleven participants, some categories emerged and evolved into theoretical ideas about the data (Charmaz, 2008b). These categories were used to develop a theory that describes students’ behavior and attitudes in their college math courses, and identifies differences between students with matched math SE and competence/knowledge and students showing a gap between these two factors. These categories are described in detail in this chapter.
Persisting in college math courses: Several students expressed their will to continue taking math courses immediately after their first experience in college-level math courses regardless of whether they passed or failed. Some students talked in a detailed way about how they were planning to take all the required math courses to complete their engineering degree. These students were hoping to take all math courses sequentially, one math course every semester, showing good confidence in their abilities to complete all the math courses without experiencing major setbacks:

I think I'm going to pass this math class and then, my plan is to take Long Calc II and Calculus II through the summer, so I can finish [first year engineering] by the end of the academic year.

Other students talked about taking a math course after finishing their math course at the time of the interview, but they just talked about the following math course: “I'm taking that class [Long Calc II] over the summer, and that would allow me to have more time to focus on that specific class and study a little bit more.” These students were hesitant about their math competence/knowledge being good enough to complete more advanced math courses later without facing some struggles:

I think Calculus I… I'll be taking it during the summer, so I can focus all my time on that. So I feel pretty good about passing that, especially having my... I already kind of know what to expect now 'cause I did take half a year of Calculus I, so that definitely helps. But I've heard that Calculus II is pretty hard, so I'm not sure what to think about that. So like, I've just heard for some people that Calculus II is one of the hardest math courses.
Despite having some doubts about their performance in advanced math courses and considering failing these courses a real possibility, these students showed good confidence that their basic math competence/knowledge would be good enough to complete all the math courses required by engineering majors: “I think once I get out of Precalc I will be able to finish all of them [math courses for my major].” These students were ready to take math courses more than once if they failed to complete a course the first time, and they were likely to continue trying to finish all their math courses even if they struggle in the process: “I'll try as many times as it [math course] takes me.” Most of the engineering students on this research were motivated to keep taking all the math courses required by their engineering majors based on their high math SE beliefs, but a couple of students mentioned their desire to become engineers as their main motivation to keep trying to complete their math college courses: “I will [finish all math courses required by my major] even if that takes an extra semester, or a year of college. I think I would because this [engineering] is for sure what I want to do.”

**Adjusting math SE:** Some students reported a high math SE after performing well in most of their high school math courses, and they aimed at college confident in their math competence/knowledge. These students’ high math SE changed when they had their first experiences in college math courses, realizing that college math courses were more difficult than they thought:

> I knew I've always been good at math from like elementary school up to high school, but now it is getting in more depth and in the hardest stuff I kind of... kind of don't feel like I’m that good anymore.
These students struggled to keep the class pace and understand college-level math topics, and that made them lower their math SE and adjust their beliefs about their math competence/knowledge to align better with their performance in college math courses:

When I was in Calculus I for the first month of school, I was like very low confidence. I though my best case scenario was like barely get a D average, and you know that's failing. And then I dropped down to Long Calc, and initially I felt confident although I lost confidence over the year 'cause it just never worked out.

They described a different perception of the difficulty of their math courses when they were talking about their high school math experiences compared to what they were experiencing in college math courses. They attributed this math SE adjustment to the complexity of college math topics and the different context in college math courses:

In college is not the same, each subject blends into the next section until the final, and is like remembering all the little stuff. And if you didn't have a good understanding of this blending, you can't remember how to do it . . . Is definitely more difficult, maybe just because I haven't adjusted to it yet.

Students who described adjusting their math SE beliefs described it as a “reality check”:

I didn't pass the first part of the Long Calc. It was kind of... kind of a reality check, 'cause I guess I could have studied more, went to tutoring more, and stuff to make my grade better in that class.

These students realized that they will need to work harder and spend more time working on their math material to perform well in college math courses after experiencing some
struggles: “I've been trying to understand the material more. I've been doing more, and finding some better ways to make it easy I guess.”

This reality check happened at different time of the semester for different students. For some students, reality hit after experiencing some struggles during the semester, but other students did not realize that their math SE was not matching their math competence/knowledge in college math courses until the end of the semester. Students who took longer to adjust their math SE to a more realistic level struggled to perform well and did not put in enough effort to successfully complete their first college math course due to their overconfidence in their math abilities: “Maybe if I had put a little more time on it [Precalc], then I probably would have finished.”

**Failing a college math course:** Most students showed a different behavior in a math class the second time that they took it after having failed it before: “Since I'm taking the class again, I'm putting a lot more effort into it, a lot more practice, um, and like really being involved with the course.” They were putting more effort into the course and that helped them to feel more confident about passing it: “Yes, I can pass it [Long Cal]. I'm putting a lot more effort into this semester than I did last semester.”

These students followed a better approach when taking the same course the second time, spending extra time working on their math activities, and seeking help if they struggled to understand a math topic:

I'm doing more practice problems, really being involved in the class such as working the problems in the outside ‘cause before I didn’t really do that, and I didn’t really do the homework, and the homework is a big part of the practice. Um... So
this time I feel that I'm able to time manage and plan things up better compare to last time.

They also showed to be less likely to feel frustrated or stressed when working on their math assignments, even if they needed to try to solve a math problem more than once to get the right answer:

Yeah, I'm definitely in the right place. It’s like, taking it the second time slows it down for me, and now I know. I remember last time and I'm finally getting it this time, is like a little slower, and it seems slower to me, so it's like easier to do the assignments.

Most students mentioned that having a failing experience was something unpleasant and it changed their academic plans, forcing them to move some of their courses to summer semesters or later in their college curricula:

Failing the course made me feel pretty bad, and after that I told myself I will work better the next time, so I can pass it and not have that feeling again.

Despite struggling to reorganize their following semester’s schedule and feeling disappointed after failing their first college math course, most students took this failing experience as an opportunity to get adapted to the college math courses’ context, and adjust their math SE beliefs closer to their performance in college math courses.

In high school you can sleep through your classes and still make an A. Over here you have to put effort... Of course it has changed, my confidence was like 10 or 11 in high school to like I said probably a 7 now or 6.
Although some students that failed their first college math course were overconfident about their math competence/knowledge coming from high school, this high math SE was useful to help these students to keep trying to take math courses immediately after their failing experience without feeling discouraged for their struggles performing math in college math courses:

I’m very confident. Since I took it [Long Calc] last semester. I feel like I'm just going to breeze by this class now. I know mostly everything he [the professor] is going to cover.

**Refreshing basic math competence/knowledge:** Some students were confident about their math competence/knowledge in general, but they showed a lower math SE when they were asked or required to take a college-level math course like Calculus I:

They want to put me in Calculus but I was like, no let me refresh myself and take Precalc again. ‘Cause I don't want to go and not really remember stuff. I just needed to refresh my mind because I didn't practice [math] since early December.

These students avoided taking a college-level math course as their first college math course, such as Calculus I, without having the necessary competence/knowledge:

I'm now taking Precalc, just because I want. Also because I just want to make sure of my basic skills before I try advance math courses. You don't want to try and push your way through this math, and maybe pass it, but not really get it.

These students were avoiding feelings of stress and discomfort trying to keep the pace in math courses given the challenging and complex math topics and new context like college classes.
Some students scored high enough on their CMPT to start in Calculus after coming to college with some Calculus experience from their high schools, but they chose to take a lower level math course their first semester:

I did make a high enough score to do it [take Calculus], but I just cowered to take the math thing like easy because my high school was really easy; and Clemson was like 3 times harder than that, so it was like ok I'll just learn the Clemson way and then I'll move up from there.

These students were trying to reinforce their math competence/knowledge to be able to perform better in Calculus after having some practice in a college math courses context:

The CMPT that I took put me right on the cut of line for Calculus I. so I thought that, since I have struggled some in high school I should probably take the lower level, and not get left behind and be completely lost in Calculus II. So I think I probably could have done Calculus I this semester, but I think I did the good choice.

**Spending extra time working on math:** Some students chose to spend some of their free time practicing math or trying to solve their math assignments to improve their math abilities:

I’m normally done with my classes by twelve, so I'm at the library doing work or in my room doing work with a friend. I do work at least an hour a day, at least one hour per day for math class if not more.

These students spent extra class time to practice their math material, and they look for extra resources such as textbooks, internet, or video tutorials to help them improve their understanding of math topics and solve extra practice problems:
The homework problems are generally how I've been able to study for this particular math class, because there's a lot of extra study material that we can use so I've been practicing problems a lot and it really helps.

Students spending extra time working on math usually tried to determine if they were able to solve math problems on their own, and they were likely to seek help in cases where they struggled to solve a problem on their own:

Usually I would go back through the homework assignments that we have done. And also there are extra assignments that we don’t get to in class, so I’ll just go back and practice those, and if I have a problem with one, then I'll go to my teacher and say can you help me with this and she will guide me through it.

**Taking struggles as opportunities:** Some students took their setbacks and struggles performing and learning math in college math courses as opportunities to improve their math abilities:

I would probably go back and figure out why I got it [math problem] wrong, like what I didn’t understand in class. Um, if I didn’t study that material enough, I wouldn’t wanna blow it off, I would wanna get back down and look at the real in deep part of it.

They realized that they would need to work harder, spend more time, and seek other’s help to be able to understand college-level math topics, and that realization helped motivate these students to continue working to improve their math competence/knowledge:
I feel like things [math courses] are getting harder sometimes, but as long as you want to learn, and you want to get better then you can do it. And I've always loved math so I always try to be better at it.

These students were more likely to spend extra time working on their math activities and seek help after experiencing some struggles in their college math courses, and they considered these struggles as a part of the learning process: “I think it [struggling with math] is part of your learning process because that is how I've learned in the past math classes. I generally raise my hand and ask a question to the teacher.”

They were not discouraged by struggles learning math, considering that overcoming these struggles will help them to improve their math competence/knowledge:

Well I feel that my confidence level would be about the same because even though I didn’t get it [math problem] right the first time, um, I can take a different approach and do it again. I don’t think my confidence would be too detrimental from that.

**Seeking help:** Some students were looking for help to complete a math assignment or resolve doubts that they feel that they cannot handle on their own:

If my way is just not working at all, then I go back and seek help from people that I know have the means to give me the right answer, or tell me how. I like to ask everybody between teachers, tutors, other classmates or even friends I had in class before.

These students usually asked their friends or professors for help during class time when they were struggling to solve a math problem, but they were also likely to look for help outside class time:
Usually the first person I go to is like a friend or a classmate, and then I probably go to office hours with my professor, and then I live in dorms, so we have tutoring every night. So I can go to tutoring.

These students normally made use of structured support systems offered by the university such as office hours, tutors, or supplemental instruction (SI), but they also looked for help from their friends and relatives if they were good at math:

I found my tutor and go to them, I go to RISE tutoring… I go with my sister sometimes… Yeah I call people to help me… I mean somewhere must be a tutor; somewhere someone understands. If I second guess myself about it then I know that I need to ask someone.

These students were more likely to spend extra time working on math related activities when social support systems were there to help them to understand their math assignments, thinking that having someone to help them would be the best way to address their doubts:

When I get helped, it just helps me to remember more, 'cause when you go to ask someone you kind of recall the conversation. I do office hours definitely with the teacher, but if it is a minor homework problem. I go with my friends, or my roommate, or anyone that I know they are good at math, or they are in a higher level of math than I am. So you know they will know the problem or the topic I'm working on and they can help me.

**Lacking college-level math experience:** Some students got to college without experience taking a college-level math course such as Calculus. These students did not to take Calculus
for different reasons: they decided not to do it, their advisor told them to focus on different courses, their high school did not offer it, or they were not ready to take it:

In my high school I took Algebra in middle school, then Algebra and the Geometry, and I take Precalculus in... I was about to take Calculus but I didn't want to ‘cause…

It was senior year so the last classes I took were better for what I was looking. Students without Calculus experience in high school were less prepared than their classmates with some Calculus experience, and they usually struggled to keep up with the pace in college math courses. Other students took a Calculus course in their high school, but they stated that expectations were very low and they did established a strong foundation in Calculus:

The high school I came from, you can sleep in class and still make an A. I left out of my Calculus class with a 104. I'm telling you it was really easy, it was horrible… high school basically held my hand the whole way.

There were some students who took an OK Calculus course in high school who struggled with the college-level courses’ pace and difficulty level:

I guess Precalc is definitely the best fit, mostly because in Calculus I I didn't know what was going on, 'cause the Calculus concepts thing [his Calculus course in high school] didn't help at all. Especially like, you know when I got there they were talking about the idea... just solving problems and I was like, I don't even know what they are doing right now. I was prepared for Precalc, definitely nor for Calculus I. This Precalc is a good representation [of his math competence/knowledge] and Calculus I was a little too high for me.
Feeling overconfident: Some students were feeling overconfident about their math competence/knowledge when they started taking college math courses, feeling that they would learn math easily: “I really understand it, I can get the math faster than the other subjects, and I did math earlier in high school. I finished math before others so yeah I just like it.” These students reported a high math SE, but they did not support their confidence in their math abilities with high performance in their math courses. High math SE made these students believe that their math competence/knowledge would be good enough to complete their college math courses without spending extra time working on their math assignments or seeking help to solve doubts when they struggled:

Well the first time [taking Long Calc], I was under the assumption that ‘Oh I know this stuff, I don't have to study as much as thought I did,’ and I didn’t put as much practice as you need to do it.

The gap between these students’ high math SE and a lower math competence/knowledge generated a problem for some students. These students were overconfident, thinking that they will be able to perform as well in college courses as they did in high school without practicing to improve their basic math competence/knowledge:

It got so much easier when I dropped to Long Calc that I think that I got a little too comfortable. I wasn't putting in all the time, and I wasn't practicing enough. So like I said when I went into the test, even if I could do the problems, I went into all four tests being able to do the problems, but not being able to do them fast enough to finish the test on time.
Students that felt overconfident in their first college math course usually performed poorly and reported negative behaviors in class such as lacking effort, procrastinating, or blaming other factors as the reason for their poor performance. Students that failed their first college math course because of their overconfidence about their math competence/knowledge were more likely to adjust their math SE the following semester. These students decreased their math SE to be closer to their actual performance in college math courses, and that also modified their behavior and attitudes taking math courses.

**Lacking effort:** Some students did not spend extra time working on their math assignments or trying to find the answer to math problems that they did not understand in class:

[In case of struggling] I would look back at the equation and see how I worked it out, and if I don't see something wrong in how I worked it out, then I kind of just...

I just stop if I don't know where to go from there.

These students did not show interest in improving their math competence/knowledge, and they did not try to solve their homework unless it was a majority of their final grade: “If is an online homework that really doesn’t matter in terms of your grade, I will honestly skip it.” These students were likely to wait until the test day was very close, or until they felt like they were getting behind the rest of class before spending more time studying: “Sometimes I get behind. If I feel like I'm getting too behind, then I try to do more hours and get more objectives.” Students who were lacking effort in math courses were less likely to seek help, even if they were struggling to understand the material.

Some students procrastinated before spending extra time trying to improve their math competence/knowledge. These students chose to spend their time doing assignments
in other courses, extracurricular activities, or something pleasurable instead of working on their math material, thinking that they would easily finish all their math assignments in a short period of time:

When I get frustrated with ALEKS or with a certain problem, then I stop doing it for a little while. And then I come back to it because it would be stressing if I just keeping doing it wrong.

These students normally struggled to complete their math assignments on time, and that made them more likely to fail their math course and finish the semester with a poor understanding of the math material taught:

Maybe if I had put a little more time on it, I probably would have finish. Yeah I will say that… I think I put a good amount of time for it, but I guess the time for ALEKS is more time than I actually have. It’s just easier to just like put it off, like OK I'll just do this tomorrow.

**Blaming other factors:** Some students blamed external factors for their poor performance in college math courses:

I just cannot keep up with this [Calculus I]. It was kind of weird because of the teacher I had, it was his first year and he definitely did not have like good teaching abilities.

These students were confident that their math competence/knowledge was good enough to perform well in their college math courses, but after experiencing some struggles, they blamed other factors such as the college instructors’ teaching style, the online material in Precalc, or the fast pace in college courses, for their poor performance.
It's online [Precalc] so that's my biggest problem. It's all taught on ALEKS, so that's not really my style. So I'm a little bit behind in like the pace they want me to be at, but as for understanding the material I'm doing pretty well.

They did not acknowledge lack of understanding or poor math preparation as the reason for their struggles performing math in college courses, and they were confident that would perform better without these external factors:

It’s not hard, is just the amount of material, and sometimes the computer gives you an example and you are trying to understand what the computer is saying, and trying to teach you, and that's kind of hard… It is easier for me having a person to teach me.

**Experiencing stress working on math:** Some students reported feelings of stress and frustration when they were struggling to solve a problem or understand a complex math topic:

I'm relatively ok [working math] until I get a problem wrong, and then when I reworked it the first time and it's wrong in a different way, then I get like really frustrated because I tried it in two different ways and it didn't work.

These students did not report experiencing these negative feelings every time that they were working on math activities, only when they struggled to understand a math topic correctly:

I don't even think that I hate math, 'cause I enjoy talking about mathematical concepts with professors. I just hate the struggle. I hate when you can't do it, and
you sit there over ten online homework problems for hours and is like... if I could
do this in 20 minutes, math would be my favorite subject.

These feelings of stress and frustration made students more likely to stop working on their
math activities and feel less confident when they talked about taking advanced math
courses in the future: “It [math course] was like full of big problems. That would be hard
for me, I don't think I want to face that again.” Students who experienced stress feelings
working on math were more likely to change their perception about math courses, even if
they used to like math course in high school: “Math used to be my favorite subject before
I came here. Now my favorite subject is engineering.”

Other students were more likely to feel stressed when they were getting ready for a
test. These students reported feelings of anxiety and stress trying to study for a math test,
and taking the test, which affected their performance and math SE:

I always do worse on tests than I do on homework, even though it is the same kind
of problems. I think just because test anxiety and stuff. Which seems to be a little
bit worse in math.

3.3 Mixed Results

All students reported a math SE ranging from medium to high, and they revealed
high confidence about their general math abilities during the interview. Despite students’
good confidence about their math abilities, some of them indicated having some
deficiencies in their math competence/knowledge (see Table 3.8). Other students revealed
a better math competence/knowledge that they thought they had. Thus, they were rating
their math SE lower than the actual math competence/knowledge they possessed (see Table
This mismatch between students’ math SE beliefs and their real competence/knowledge affected these students’ behavior and attitude in math courses, making them more likely to behave in certain way depending on the type of mismatch. Specifically, students with a high math SE and lower math competence/knowledge were more likely to show positive behaviors in math classes that could help them to develop better math abilities. On the other hand, students with a medium math SE and a higher math competence/knowledge were more likely to have negative behaviors in math classes that hindered their possibilities to improve their math abilities. Another group of students showed a good balance between their math SE and their math competence/knowledge (see Table 3.8).

Table 3.8: Students’ math SE and their actual math competence/knowledge comparison.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Math SE</th>
<th>Math Competence/Knowledge</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>P Spring 2014</td>
<td>6.6</td>
<td>81</td>
<td>Mismatch</td>
</tr>
<tr>
<td>L Summer 2014</td>
<td>7</td>
<td>91</td>
<td>Mismatch</td>
</tr>
<tr>
<td>P Fall 2014 (1 of 2)</td>
<td>7.6</td>
<td>15</td>
<td>Mismatch</td>
</tr>
<tr>
<td>P Fall 2014 (2 of 2)</td>
<td>8</td>
<td>29</td>
<td>Mismatch</td>
</tr>
<tr>
<td>L Spring 2015</td>
<td>6.2</td>
<td>73</td>
<td>Mismatch</td>
</tr>
<tr>
<td>P Spring 2015</td>
<td>6.8</td>
<td>67</td>
<td>Match</td>
</tr>
<tr>
<td>L Fall 2015</td>
<td>7</td>
<td>85</td>
<td>Mismatch</td>
</tr>
<tr>
<td>L Spring 2016 (1 of 3)</td>
<td>6.5</td>
<td>66</td>
<td>Match</td>
</tr>
<tr>
<td>P Spring 2016</td>
<td>9</td>
<td>83</td>
<td>Match</td>
</tr>
<tr>
<td>L Spring 2016 (2 of 3)</td>
<td>6.9</td>
<td>65</td>
<td>Match</td>
</tr>
<tr>
<td>L Spring 2016 (3 of 3)</td>
<td>7.8</td>
<td>82</td>
<td>Match</td>
</tr>
</tbody>
</table>

Math SE average was rated from 1 to 10 and math competence/knowledge from 1 to 100.

These students with an aligned perception of their math abilities and performance in college math courses show a different behavior in math courses than the other groups. In particular, they were more likely to make decisions that would increase their math
abilities and help them overcome struggles. A detailed description of these students’ behavior, depending on their math SE and math competence/knowledge comparison, will be presented in the next chapter.

Some students clustered together after analyzing and comparing their math SE beliefs with their math competence/knowledge (see Figure 3.2). Students that clustered together showed similar behaviors and attitudes while taking math college math courses, and these behaviors and attitudes were used to develop the categories described in the previous section. These categories were the baseline to start developing a theory that explains how math SE of first year engineering students with poor math preparation influences their performance and behavior in college math courses.

![Figure 3.2: Students’ math SE comparison with their math competence/knowledge and how they clustered according these two factors.](image)

*C/K = competence/Knowledge*

Figure 3.2: Students’ math SE comparison with their math competence/knowledge and how they clustered according these two factors.
CHAPTER FOUR
DISCUSSION AND CONCLUSIONS

4.1 Discussion

The engineering students that participated in this research showed substantial confidence in their math abilities, reporting medium and high math SE beliefs during their first college math courses. These engineering students were confident that they could perform college-level math even when they were placed in non-college-level math courses due to poor math preparation in high school. Students were more confident in their math abilities when talking about performing math in general or successfully completing their college math courses than when they talked about performing specific math tasks they had struggled with in the past such as solving math word problems, or working with graphs. High math SE beliefs could influence students’ decisions to pursue an engineering major (Lent et al., 1991; Siegel et al., 1985), thus it was expected that these engineering students would indicate high levels of confidence in their math skills. Having relatively high math SE has been shown to be positively related to students getting involved in math related activities and trying to overcome difficulties if they struggle to understand the material in their math courses (Pajares & Graham, 1999; Pajares & Miller, 1995; Zimmerman, 2000). But findings of this study show that having relatively high math SE beliefs could lead engineering students to different behaviors and performance in their math classes depending on the level of math competence/knowledge that they have to support their beliefs about their math abilities.
4.2 Engineering Students with a Mismatch between their Math SE and their Math Competence/Knowledge

4.2.1 Engineering Students with a Mismatch between a High Math SE and a Lower Math Competence/Knowledge

Engineering students that showed a mismatch between a high math SE and a lower math competence/knowledge (see Figure 4.1) are more likely to be overconfident about their abilities to perform well in their math courses. These students normally struggle to complete their math assignments on time because they believe they will need less time to understand their math course material than they really need. They also struggled during their first experience taking a college math course, and usually blamed external factors for their poor understanding of the class material, such as the online course format, or the lack of an instructor to set the class pace and explain challenging topics. These engineering students started their math college classes thinking that the math material would be easy to understand because they had developed the idea that math courses are not very challenging due to their high school experiences. Students that avoided taking Calculus in high school may have an inflated sense of their math abilities because of their experience taking basic math topics that did not challenge their math understanding. Although current literature suggests that a high math SE may have a positive impact on students’ behaviors in math classes (Gore, 2006; Schunk, 1991), engineering students with high math SE need to be cautious about thinking that their math abilities exceed their actual math competence/knowledge, especially if their beliefs are based on their performance in basic math courses. If these students’ math competence/knowledge is considerably lower than
their math SE beliefs, they could experience setbacks in their math education once they try to perform well in college-level math courses like Calculus. Facing struggles and setbacks in college math courses due to feelings of overconfidence could lead engineering students with low math competence/knowledge to spend less time working to improve their math abilities.

Engineering students with a mismatch between a high math SE and a lower math competence/knowledge are likely to experience feelings of stress and anxiety when struggling on their math material because they believe they should be able to learn the course material and perform well without much effort. The stressed and anxious feelings usually lead these students to stop working on their math material, making them get behind and less likely to improve their math abilities (Jameson, 2013; Meece, Wigfield, & Eccles, 1990). Although these students are likely to get behind schedule in their math course due to their frustration feelings struggling in math courses for the first time and that usually lead them to fail it, they took this failing experience as an opportunity to refresh their basic math knowledge. This positive attitude about failing their first college math course helped these students to keep their confidence in their math abilities high so they could complete the same course the following semester. They did not mention having a plan to change their approach taking the same math course the following semester, but they acknowledged that math courses in college are more difficult that they expected coming from their high school. Realizing that their high school math preparation was not at the level they believed may influence these students’ math SE beliefs, making them more likely to lower their math SE closer to their math competence/knowledge in future college math courses. Students will
more likely approach the course with a more realistic view of their math abilities and a better understanding of the time that they would need to spend on their math material to complete the course. Further research should be conducted with more students with high math SE and lower math competence/knowledge during their first college math course to analyze the way that these students respond to struggles in their first college math course. These students are usually overconfident about their math competence/knowledge and they adjust their math SE beliefs after failing their math course. Knowing more about engineering students’ math SE evolution according to their performance in their first college math course before they fail the course could help math educators better advise their students. Findings of this future research could be used to develop more efficient strategies to advise engineering students with poor math preparation, and provide them with enough opportunities to adjust their math SE and change the negative behaviors and attitudes related to overconfidence feelings taking a college math course.

Figure 4.1: Attitude and behaviors of engineering students with a mismatch between a high math SE and a lower math competence/knowledge.
4.2.2 Engineering Students with a Mismatch between a Medium Math SE and a Higher Math Competence/Knowledge

Students that reported a medium math SE with a higher math competence/knowledge (see Figure 4.2) are more reluctant to get involved in challenging math activities and take advanced math courses for which they do not feel prepared (Manley & Rosemier, 1972), even when some of them have taken courses like Calculus in high school. The students’ decision to start in a non-college-level math course, even though they may be prepared for higher levels, may be because they are trying to refresh their prior math knowledge before taking a college-level math course. They are usually confident enough about their math abilities to sufficiently complete the math courses required by their engineering major, but they are cautious about the possibility of struggling with more advanced math topics. They believe that college math courses are more challenging than their high school courses, and they are more likely to look for a math course that could let them adapt to the different teaching style and difficulty level of college math courses without feeling rushed or getting behind when transitioning into college.

These engineering students are likely to have positive behaviors and attitudes in college math classes, spending extra time working on their math assignments, seeking help in case they struggle to understand any math topic, and remaining motivated to improve their math abilities even when they are facing struggles in understanding new math topics. They normally put in more effort to learn new and challenging math material, but they are likely to wait until they get help by someone to continue working on a math problem they fail to initially solve on their own. They usually prefer to have the instructor guide them by
explaining the step-by-step solutions to math problems, and they normally seek help before giving up. Although seeking help before giving up helps these students believe that they can complete advanced math courses if they find the right support systems, these beliefs may also generate poor confidence in their math abilities when they are working on their own and there is not one to help them in case they struggle (Hackett, 1985).

Engineering students with medium math SE with a higher math competence/knowledge work diligently to improve their math competence/knowledge. They usually view struggles in learning math as opportunities to test their real understanding and improve their math abilities. They consider struggling as a normal part of learning advanced math topics. These students reported confidence in their abilities to complete all the math courses required by engineering majors, and are likely to work harder to improve their math abilities when they struggle in more advanced math courses.

Figure 4.2: Attitude and behaviors of engineering students with a mismatch between a medium math SE and a higher math competence/knowledge.

4.3 Engineering Students with a matched Math SE and Math Competence/Knowledge
4.3.1 Engineering Students with a Matched High Math SE and Math Competence/Knowledge

Engineering students that reported a high math SE which was aligned with their math competence/knowledge (see Figure 4.3) are likely to show positive behaviors and attitudes in college math courses. Such behaviors include spending extra time working on their math material, seeking extra help from tutors, and attending office hours (Zimmerman, 2000). These students usually view their struggles learning math as part of the math learning process, and they consider these struggles as opportunities to improve their math competence/knowledge (Robert W. Lent et al., 1991). They enjoy the challenge in learning new and/or advanced math topics. They were very confident about completing the math courses required by their engineering majors, and they were prepared to take more advanced math courses more than once even if they failed the course the first time (Multon et al., 1991; Suresh, 2006).

![Figure 4.3: Attitude and behaviors of engineering students with a matched high math SE and a high math competence/knowledge.](image)

Behavior in Math Class
- Spending Extra Time
- Seeking Help
- Taking Struggles as Opportunities
- Adjusting Math SE

Attitude towards
- Failing Experience (learning from it)
- Persisting in College Math (desire for it)

Engineering students with a high math SE which was aligned with their math competence/knowledge reported changing their approach taking a college math course
after their failing experience in their first college math course. They took this failing experience as a wake-up call that helped them to realize that they would need to spend extra time working on their math material, seeking help to improve their math abilities to stay on pace with the class at the college level. They did not lose confidence in their math abilities after failing their first college math course, but they use their failing experience to adjust their real math competence/knowledge to more realistically align with their math SE beliefs. Keeping a high math SE that was better aligned with their math competence/knowledge helped these students to feel motivated to work harder the second time that they took the same math course (Bandura & Schunk, 1981; Walker et al., 2006). These students spent extra time working to improve their math abilities on their own during their college math course and they were most likely to seek help if they struggled to understand a math topic (Williams & Williams, 2010). This was confirmed by their improved performance when taking the same math course that they failed the semester before.

4.3.2 Engineering Students with a Matched Medium Math SE and Math Competence/Knowledge

Engineering students that reported a medium math SE that was aligned with their math competence/knowledge (see Figure 4.4) are likely to experience stress if they struggle working on math problems. These students usually lack college-level math skills coming from high school (Gardner, Pyke, Belcheir, & Schrader, 2007), and that poor understanding of advanced math topics could be a problem when they take their first college math course. They normally blame external factors such as the instructor’s teaching style, and the fast
class pace for their failing experiences in college math courses, but they usually show limited interest in spending extra time working to improve their math abilities on their own. This lack of effort in trying to improve their math abilities could make these students more likely to experience struggles and fail the first time that they take a college math course. They students usually think that their math competence/knowledge is acceptable to pass the course without working hard to improve their math abilities causing them to remain in a comfort zone where they overlook the importance of hard work and practice in math courses (Lent et al., 1984).

After their failing experience engineering students with a medium math SE that was aligned with their math competence/knowledge realized they would need to work harder and spend more time working on their coursework to be able to complete all the math courses required by their engineering majors. Their failing experience showed them that their math courses were more difficult than expected, and they would need to lower their math SE beliefs to align with their ability. This math SE adjustment brought their math SE beliefs closer to their real math competence/knowledge, making these students more likely to seek help when struggling with math topics (Lopez & Lent, 1992). Although these students showed more interest in improving their math abilities the second time they took a college math course, they remain more likely to stop trying to solve math problems if they are struggling and there is no one there to help them understand what is wrong with their approach. They are also likely to persist in repeating math courses they had failed, viewing their failing experiences as opportunities to refresh their math competence/knowledge and perform better next time (Middleton et al., 2015).
Figure 4.4: Attitude and behaviors of engineering students with a matched medium math SE and a medium math competence/knowledge.

4.4 General Discussion

Engineering students in this study reported a relatively high math SE, especially when they were talking about their abilities to perform math in general and their confidence in completing all the math courses required by their majors. Engineering students usually choose engineering as their major being confident in their math competence/knowledge and believing they can perform well in math related activities (Hackett & Betz, 1989; Lent, Lopez, & Bieschke, 1991.) Most of the engineering students in this work were very confident that they would successfully complete their first college math course, even when they had poor math preparation coming from high school. The gap between high math SE and low math competence/knowledge leads students to negative behaviors and attitudes in math courses such as feeling overly confident about their math competence/knowledge, blaming other factors for their struggles and failing experiences, and lacking effort trying to improve their math abilities (see Figure 4.5). These negative behaviors and attitudes create a stressful environment in engineering students’ math courses, making them more likely to perform poorly and fail their first college math course.
All engineering students that showed a match between their math SE beliefs and competence/knowledge were repeating their college math course at the time of the interview. Having a failing experience in their first college math course put engineering students in a position where they had to adjust their math SE to a lower level, closer to their real math competence/knowledge. These students’ math SE remained high enough to make them think that they still can complete all the math courses required by their majors, but after failing their first college math course, they were more likely to show a match between their math SE and their real math competence/knowledge. This new and more realistic perception of their math competence/knowledge helped these students modify their behavior and attitude when taking a college math course the following semester. Students with math SE beliefs aligned with their math competence/knowledge are more likely to have positive behaviors and attitudes in math courses such as spending extra time working on their math material and seeking help to address their doubts (see Figure 4.5). Although engineering students realized that college math courses would be more difficult than they thought they would be, they did not get discouraged by their failing experience and remained confident about completing their math courses.

Engineering students are likely to remain confident about their math abilities despite facing some setbacks in their college math courses. Interestingly, after failing their first college math course, some students lowered their math SE while others’ math SE beliefs remained high. Students who adjusted their math SE beliefs to a value that matched their basic math competence/knowledge in a more realistic way were more likely to experience stress when struggling to understand a math topic, and normally stopped trying
to complete their math assignments without external assistance. Other students viewed their struggles in learning math as an opportunity to develop better math competence/knowledge. These students’ math SE remained high even after failing their first college math course, but their behavior and attitudes changed when taking the same course the following semester. By adjusting their approach, the students were better able to develop their math competence/knowledge. Students with a high math SE aligned with their math competence/knowledge are likely to show positive behaviors and attitudes in math classes such as spending extra time working on their math assignments, seeking help to address their doubts, and believing their struggles in learning new math topics as opportunities to develop better math abilities and gain a deeper understanding of the course material. Engineering students that reported a high math SE that matched their competence/knowledge usually enjoyed the challenge involved in learning new difficult math topics, and they considered that struggling to solve math problems is part of the learning process.

*Positive Behaviors and Attitudes: spending extra time, seeking help, and taking struggles as opportunities; Negative Behaviors and Attitudes: lacking effort, experiencing stress, blaming other factors, and overconfidence.*

Figure 4.5: Engineering students with poor math preparation behaviors and attitudes in college math courses according to their math SE and competence/knowledge level.
Engineering students in this study were confident that they would finish all the math courses required by their major (see Figure 4.5). They reported great confidence in their math abilities during their first math college math course, even after failing their first math course. Even though students reported struggling with the pace of the course and understand some math topics in a college math course, their confidence in their math abilities remained relatively high. This medium to high math SE belief level made these students believe that they would be able to satisfactorily complete all the math courses required by their majors if they worked hard and put in extra effort to improve their math abilities (Bandura, 1980; Marra, Rodgers, Shen, & Bogue, 2009; Walker et al., 2006). They were confident about their abilities to complete their college math courses even if they would need to repeat some of the most advanced courses due to failing to pass them the first time.

4.5 Conclusions

Engineering and mathematics educators should be aware that engineering students are likely to have high math SE beliefs coming from high school, believing they can perform well in college math courses even when they have some deficiencies in their math competence/knowledge. Math instructors should be prepared to advise and effectively motivate engineering students with a poor math preparation that are not ready to take a Calculus course when they start their college education. Engineering students are likely to get overconfident about their math abilities, tend to procrastinate in class, put little effort trying to improve their math abilities, and blame other factors for their struggles in learning
new math topics. The combination of these beliefs, attitudes, and actions may result in them failing their first college math course. Although these students will normally use their failing experiences to adjust their math SE beliefs closer to their real math competence/knowledge level, positively changing their behaviors and attitudes in future math courses, math instructors should warn engineering students with poor math preparation about the risk of having a mismatch between high math SE beliefs with lower math competence/knowledge. Instructors should inform students about the potential negative behaviors and attitudes related to students with overestimated math SE beliefs. If math instructors and educators could present evidence of engineering students’ high math SE beliefs and how these beliefs are not always supported by high math competence/knowledge to perform in basic math courses, then these students may be more receptive to instructors’ advise to get involved in math related activities aiming to improve their math competence/knowledge. Being aware of the possible negative behaviors that an engineering student could have in college math courses due to a mismatch between their high math SE and lower competence/knowledge could help them to reflect on their competence/knowledge more realistically. Giving engineering students the opportunity to reflect about their math SE beliefs early in their first college math course may help these students to adjust their math SE beliefs closer to their real math competence/knowledge before failing their first college math course. Developing and analyzing the results of an intervention that measures engineering students’ math SE and compares their math SE beliefs with their performance in their first college math course will help to determine the best way to inform students about their behaviors and attitudes in college math courses.
The need of this type of math SE intervention will be addressed as a future direction of this research in the following chapter. If these engineering students are advised to align their math SE beliefs closer to their math competence/knowledge, they may be more likely to avoid the negative behaviors described above and be more engaged in activities that could help them to improve their math competence/knowledge and avoid failing their first math course in college.

This research contributes to the math SE literature suggesting that high math SE beliefs that are not supported by a similar math competence/knowledge could lead to negative behaviors and attitudes such as overconfidence, lack of effort in math classes, laying blame on other factors for their struggles learning math, and feelings of stress and anxiety performing math activities which ultimately lead students to perform poorly and fail their first math college math courses.

Despite the negative behaviors and attitudes related to engineering students that show a gap between a high math SE and lower math competence/knowledge, these students are very likely to keep trying to complete the math courses required by their majors regardless of facing failing experiences because of their high levels of math SE. Engineering and math educators should try to take advantage of this persistence shown by engineering students by trying to engage them in math related activities. Educators should suggest to students that spending extra time trying to improve their math abilities and seeking help to address their doubts will be useful skills to develop for when they face more challenging topics in their future advanced math. Instructors should encourage their engineering students with poor math preparation to address their math deficiencies during
the first weeks of the semester, helping them to understand that their math competence/knowledge may not be as strong as they believe while they try to keep their high math SE. Making students aware of their math deficiencies could make this students more likely to have positive behaviors in math classes such as, spending extra time working on their math material, and seeking help to address their doubts trying to improve their math understanding. Students with high levels of math SE are likely to respond positively to an instructor’s constructive feedback about their math deficiencies as their math SE enables them to not only enjoy working on math related activities, but they will also feel capable to perform well on them.
CHAPTER FIVE
FUTURE DIRECTIONS AND LIMITATIONS

5.1 Implications for Research

This research contributes to the math SE literature (Betz & Hackett, 1983; Hackett & Betz, 1989; Lopez & Lent, 1992; Zeldin et al., 2008) by expanding the understanding of math SE beliefs that are not well supported by actual math competence/knowledge. There are a limited number of studies that investigate the effects of math SE on engineering students’ behaviors in math courses (Brown & Burnham, 2012). This dissertation research shows that students may have different behaviors and attitudes in math classes depending on a possible gap between their math SE beliefs and their math competence/knowledge. The emerging theory describes the negative effects of high math SE beliefs of engineering students with poor math preparation. The negative effects of having a gap between a high math SE and lower math competence/knowledge suggested by this research’s findings is not included in current math SE literature (Bandura, 1986; Hackett & Betz, 1989). This emerging theory can motivate further research on engineering students’ attrition and poor performance in college math courses.

5.2 Implications for Practice

A better understanding of the effects of high math SE beliefs on engineering students behaviors and attitudes in their college math courses, particularly those with poor math preparation, could help engineering and math instructors to better advise these students. Math instructors should be prepared to deal with students’ feelings of overconfidence about their math abilities and take advantage of this common high math
SE to promote student engagement in math classes and in math related activities outside class. Freshman engineering students are likely to be reluctant to spend extra time working on their math assignments because they often believe that their basic math competence/knowledge will be good enough to perform well in their college math courses. This is where math instructors should be ready to recognize this type of overconfident behaviors and warn students about the importance of practice, hard work, and seeking help to address their doubts in college math courses, especially if students are struggling to keep the pace in class. Math instructors should be trained to talk about the possible gap between engineering students’ math SE beliefs and their math competence/knowledge. Math educators and instructors should be ready to offer students different options to get involved in math-related activities that may provide students the extra opportunities that they need to improve their math competence/knowledge (Karabenick & Knapp, 1991). Math instructors should be aware that students math SE is an important factor for engineering students retention in math courses and engineering majors, and they need to support these students’ math SE beliefs with positive comments (Lent et al., 1991) while they used evidence to help students realize that they need to work harder to improve their math abilities in order to match their high math SE beliefs with high math competence/knowledge for their college math courses.

Helping math instructors to recognize the negative behaviors and attitudes of engineering students with poor math preparation in college math courses could have a positive impact in the way that students are advised and motivated in class. If freshmen engineering students are advised to avoid specific behaviors and feelings of overconfidence
in math, they would be more likely to identify these behaviors as factors that may negatively influence their performance in college math courses. This realization could help them to adopt a better approach to taking a college math courses for the first time. Advising and motivating engineering students with poor math preparation in the right way could help to address the high levels of engineering majors’ attrition (Geisinger & Raman, 2013), which is more prevalent in students starting in non-college-level math courses (Van Dyken et al., 2015).

5.3 Future Directions

These research findings are a good starting point to develop a thorough theory that could explain the choice of behavior and attitude in college math course for engineering students with poor math preparation. Although students were classified in groups depending on their math SE level and how well this math SE was aligned with their real math competence/knowledge, and the behaviors and attitudes of students in each group were described in detail, the causality of these behaviors and attitudes leaves room for additional research aiming to complement this emerging theory. Future research will be conducted to determine the reasons why students in different groups are likely to choose certain behaviors in math classes depending on their math SE level and how well this math SE is representing their math competence/knowledge. To find the reasons why students are more likely to behave in a certain way, more students need to be interviewed to expand the findings of this grounded theory. These additional students should be purposely selected following theoretical sampling to complement this emerging theory. Additional participants will be added to the grounded theory until reaching theoretical saturation with
data that describe students experiences in a rich way (Bryant & Charmaz, 2007), which was not possible to reach during this research due to participant recruitment limitations. Additional students with a mismatch between a high math SE and lower math competence knowledge will help to determine the factors that influenced their high confidence in their math abilities, and what college experiences could help them to have a better estimation of their math competence/knowledge. Knowing more about the sources of engineering students’ high math SE beliefs could help to lead future research, aiming to find the causality of student choice of behaviors and attitudes and determine the role that college math instructors should take to help their students to choice positive behaviors that could help them to improve their math abilities and keep their high math SE beliefs. To further understand the math instructors’ role on students’ choice of behaviors and attitudes, a study using a brief intervention showing college students their math SE scores together with their math performance in their college math courses will be conducted to compare these two factors. Giving students the opportunity to realize how well they support their math SE beliefs with actual math competence/knowledge could help math instructors advise students in a better way, using evidence about the possible gap between these two factors and showing students the negative behaviors related to having a big gap between a high math SE and lower math competence/knowledge.

Aiming to bring light to the causality of students’ choices of behavior and attitudes and their relationship with students’ math SE beliefs and math competence/knowledge, the grounded theory data collection interview protocol will be modified. Several items asking students about their mathematics identity (Cass, Hazari, Cribbs, Sadler, & Sonnert, 2011;
Cribbs, 2012; Grootenboer & Zevenbergen, 2008) and engineering identity (Godwin, 2016; Meyers, Ohland, Pawley, Silliman, & Smith, 2012) will be included. These items will foster a deeper understanding of students’ persistence in engineering majors through the addition of factors including recognition and interest in engineering careers. Interview data related to identity can help determine the effects of recognition and interest on students’ perceptions of their math abilities to complete the math courses required by engineering majors. Finding a possible relationship between math and engineering identities and math SE development and persistence would expand this emergent theory by bringing light to the reasons why engineering students choose certain behaviors and attitudes, and what type of experiences could make them modify these particular behaviors.

5.4 Dissemination Plan

Findings of this research are of interest to engineering and mathematics educators, instructors, and researchers. Findings will be presented at both mathematics and engineering education international conferences such as the International Group of Psychology of Mathematic Education and the American Society for Engineering Education. Additionally, this research will be formatted to be submitted to peer-review research journals such as the *Journal of Engineering Education*, the *Journal for Research in Mathematics Education*, and/or the *Journal of Mixed Methods Research* for publication. The methods followed during this research could be of special interest to the mixed methods research community due to their unique cyclical participant selection and analysis approach (see Figure 2.1). The combination of an explanatory sequential design (Creswell & Clark, 2011) and the theoretical sampling used to select following participants in the
grounded theory (Bryant & Charmaz, 2007) created a recurrent loop in the collection and analysis of both qualitative and quantitative data in a sequential way. This loop could contribute to the mixed methods design literature. Hence, its implementation in future research will be addressed and described in detail, aiming to participate in mix methods conferences in the future.

Findings and final outcomes of this research will be translated to Spanish, and will be submitted for publication to the Mexican National Council of Science and Technology (CONACyT) Journal. This research will also be replicated in the Mexican context to determine the math SE influence on Mexican engineering students’ behaviors and attitudes. A math SE measurement instrument will be developed based on the MSES items. This new survey’s validity will be tested for this different population, and it will be used for theoretical selection. The interview protocol will be translated to Spanish and modifications and edits will be done after analyzing the first interviews following the same grounded theory approach. Findings of the replication of this research in a Mexican context will help to develop a better theory that explain math SE effects on engineering students choice of behavior and attitude by comparing and contrasting the final outcomes.

5.5 Limitations of this Research

This research described how engineering students with poor math preparation behave in their first college math course depending of their math SE and competence/knowledge levels. Despite the small population of engineering students placed in non-college-level math courses due to poor preparation, the sample for this research was broad enough to collect the necessary qualitative and quantitative evidence to classify
students’ behaviors and attitudes in college math courses according to the correlation between their math SE beliefs and competence/knowledge. This research should be viewed in light of the limitations of the small available population and the complexity of the theoretical sampling to select the most appropriate participants for the qualitative phase of this research.

In order to reach theoretical saturation with respect to a deeper understanding of the causality of these behaviors and attitudes, a larger sample would be required to complement the emerging theory conducted as part of this dissertation. Collecting data from additional students with specific SE and competence/knowledge combinations would be especially beneficial for expanding theory regarding contradictions in students’ behaviors. For example, the small sample size (2 students) of the high math SE with lower math competence/knowledge cluster made determining the most likely behaviors and attitudes of students in this cluster challenging. Recruiting the specific types of participants that could help with theoretical sampling was a big challenge due to the lack of student response to the e-mail invitation. Students that did not respond to the e-mail invitation could have some reservations for talking about their experiences taking college math courses, especially if they were struggling to perform as they expected. Students performing poorly in college math courses may be more likely to report lower math SE levels, and this type of engineering student with low math SE and low math competence knowledge was difficult to find in engineering majors. None of the students reporting a matched low math SE and low math competence/knowledge in this study’s population responded to the e-mail invitation for interview. To address this recruiting limitation, future e-mail invitations
will offer students the opportunity to have tutoring with a math instructor in one-to-one sessions to help them improve their performance in addition to the Amazon card.

Limitations in ability to recruit the right student(s) to continue developing the emerging theory was the biggest limitation of this research. The sampling issue applied to both the sample size in general, and the sample size for clusters that needed more participants. Lastly, there are more Spring semester (7) than Fall semester (4) students in this research. The last qualitative data collection was performed during the Spring 2016 semester, and the last four students were repeating their math course after failing it the first time. The inability to recruit a student who has not had a failing experience adversely affected the theoretical sampling. This issue could be addressed in future research by aiming to develop a better understanding of engineering students’ behaviors and attitudes prior to having a failure experience.
REFERENCES


Cribbs, J. (2012). *The Development of freshman college calculus students’ mathematics identity and how it predicts students’ career choice*.


APPENDICES
Appendix A

Interview Protocol for the Grounded Theory Data Collection

Interview Questions

1. Why did you choose engineering as a major?
2. What were your biggest influences in choosing engineering as a major?
   - Can you rank them and explain why?
3. What kind of skills do you need to be an engineering major?
   - Any special math skills?
4. What math courses did you take in HS?
5. How did you do in those courses?
   - Did you take math courses in your senior year? Why? How did you do?
6. How do you feel about math courses in general?
   - Have you ever felt that math courses are difficult? How did that make you feel?
7. How confident do you feel that you can master the skills taught in your current math class?
   - Could you select your level of confidence in a scale between 1 (not at all) and 10 (very confident).
8. Has this level of confidence changed from the beginning of this class to now?
   - How do you feel about your academic HS math preparation?
9. What could affect your level of confidence in your math skills?
   - How does your math professor could influence your level of confidence?
10. How confident do you feel that you can do the most challenging math exercises of your class if you have all the time and resources you need to work to your satisfaction?
    - Could you select your level of confidence in a scale between 1 (not at all) and 10 (very confident).
11. How is your level of confidence in your math abilities when you are solving math problems in class against solving math problems in a test? Why?
    - Could you select your level of confidence in a scale between 1 (not at all) and 10 (very confident).
12. Let us assume that you have worked very hard and put in a lot of effort trying to master the material in your math class, but you fail your exit/final exam, how would you feel?
    - What would you do?
13. How confident do you feel that you will finish all your math classes that are required for your major?
    - Could you select your level of confidence in a scale between 1 (not at all) and 10 (very confident).
    - What would be your strengths and weaknesses?
14. What about your next Calculus course, How confident do you feel that you can get a B or more in that class? Could you select your level of confidence in a scale between 1(not at all) and 10 (very confident).
15. Has this level of confidence (getting a B+ in Calculus courses) changed since you started taking college math courses (HS vs CU)? Why?
16. How confident do you feel that you can solve math word problems or problems with math applications? Could you select your level of confidence in a scale between 1(not at all) and 10 (very confident).
   - What do you need to solve them?
17. What strategies do you use to solve a math problem? How confident do you feel that you can solve all kind of math problems using this strategy, in a scale between 1 and 10?
18. What do you do if you think your solution to a math problem seems unreasonable? How you determine if your answer does not make any sense? How confident are you that you can recognized that your answer doesn’t make sense on a scale between 1(not at all) and 10 (very confident).
19. Can you find errors in your math exercises when they are not correct? How you do that (specific strategy)?
   - Do you normally double check your answers looking for any mistake?
   - Do you need others’ help to realize that something in your solution is wrong?
   - Could you select your level of confidence about finding theses errors in a scale between 1(not at all) and 10 (very confident).
20. How confident do you feel that you can solve your homework after being taught a difficult topic? Could you select your level of confidence in a scale between 1(not at all) and 10 (very confident).
21. What would you do if you realize that you have some deficiencies in some of your math class topics?
22. How much time do you spend doing math per week (outside class time)?
   - What do you do when you work math?
23. What do you do if your first approach to solving a math exercise does not work? How do you feel if you try to solve a problems more than once? Could you select your level of confidence in a scale between 1(not at all) and 10 (very confident).
24. What do you do if you don’t understand the exercises in class? Is the same with your homework? What could be different if you don’t have access to other people help? Your level of confidence?
25. How do you determine if a diagram, sketch or table could be useful to solve a math problem? Could you select your level of confidence in a scale between 1(not at all) and 10 (very confident).
- How does drawing a diagram affect your ability to solve a problem?

26. How confident do you feel that you can handle the mathematics involved with solving engineering problems? Could you select your level of confidence in a scale between 1 (not at all) and 10 (very confident).

- What could be the most challenging part of solving this type of engineering problems?

27. Do you get stressed when you work mathematics?

- What specific activities?

- Does that affect your performance?

28. Do you think that anyone could be good at math or is just for certain kind of people with special talent?

29. How well do you think your math knowledge, skills and abilities match your current math course level?

- What about your performance in this course?

a) Reasons for choosing engineering

b) The persistence in their will to become engineers

c) Math self-efficacy

d) Social Support
Appendix B

Mathematics Self-Efficacy Survey

We are interested in the way you feel about your mathematics skills and how you perform in mathematics course. Please make your best estimate for each item and answer as many questions as possible. There are no right or wrong answers.

**Part I:** Please indicate your level of confidence on your ability to successfully perform the next tasks, confidence rating could be from 1 “Not confidence at all” to 10 “Complete confidence”

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>Work with a scientific calculator like a TI-83</th>
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<td></td>
<td>2</td>
<td>Determine how much interest you will end up paying on a $675 loan over 2 years at 14 $\frac{3}{4}$% interest.</td>
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<td></td>
<td>3</td>
<td>Figure out how much lumber you need to buy in order to build a set of bookshelves.</td>
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<td>4</td>
<td>Compute your income taxes for the year.</td>
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<td>5</td>
<td>Figure out how much material to buy in order to make curtains for your living room windows.</td>
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<td>6</td>
<td>Understand a graph accompanying an article on business profits.</td>
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<td></td>
<td>7</td>
<td>Understand how much interest you will earn on your savings account in 6 months, and how that interest is computed.</td>
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<td></td>
<td>8</td>
<td>Add two large numbers in your head (e.g., 5429 + 62745).</td>
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<td></td>
<td>9</td>
<td>Estimate your grocery bill in your head as you pick up items.</td>
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<td>10</td>
<td>Determine the amount of sales tax on a clothing purchase.</td>
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<td>11</td>
<td>Figure out the tip on your part of a dinner bill split 8 ways.</td>
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<td>12</td>
<td>Figure out how long it will take to travel from City A to City B driving at 55 mph.</td>
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<td></td>
<td>13</td>
<td>Compute your car’s gas mileage.</td>
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<td></td>
<td>14</td>
<td>Set up a monthly budget for yourself.</td>
<td></td>
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<td></td>
<td>15</td>
<td>Calculate how much you are going to pay if you want to purchase 13 identical items at 12.75 each.</td>
<td></td>
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<tr>
<td></td>
<td>16</td>
<td>Figure out which of two summer jobs is the better offer; one with a higher salary but no benefits, the other with a lower salary plus room, board, and travel expenses.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>Figure out how much you would save if there is a 15% markdown on an item you wish to buy.</td>
<td></td>
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<tr>
<td></td>
<td>18</td>
<td>Calculate recipe quantities for a dinner for 41 when the original recipe is for 12 people.</td>
<td></td>
</tr>
</tbody>
</table>

**Part II:** Please indicate your level of confidence on your ability to complete the following college courses with a grade of “B” or better, confidence rating could be from 1 “Not confidence at all” to 10 “Complete confidence”

<table>
<thead>
<tr>
<th></th>
<th>19</th>
<th>Calculus I</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
<td>Calculus II</td>
<td></td>
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<tr>
<td></td>
<td>21</td>
<td>Biochemistry</td>
<td></td>
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<tr>
<td></td>
<td>22</td>
<td>Statistics</td>
<td></td>
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<tr>
<td></td>
<td>23</td>
<td>Computer science</td>
<td></td>
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<tr>
<td></td>
<td>24</td>
<td>Trigonometry</td>
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<td></td>
<td>25</td>
<td>Economics</td>
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<td>26</td>
<td>Accounting</td>
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<td></td>
<td>27</td>
<td>Philosophy</td>
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<tr>
<td></td>
<td>28</td>
<td>Business administration</td>
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<tr>
<td></td>
<td>29</td>
<td>Geometry</td>
<td></td>
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<tr>
<td></td>
<td>30</td>
<td>Algebra II</td>
<td></td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>Algebra I</td>
<td></td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>Basic college math</td>
<td></td>
</tr>
</tbody>
</table>
Part III: Please indicate your level of confidence on your ability to successfully solve the next problems, you do not need to solve these problems to answer the surveys. Confidence rating could be from 1 “Not confidence at all” to 10 “Complete confidence”.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
</table>
| 33 | Multiply \( \frac{x-3}{x^2+5x+6} \) \( \times \) \( \frac{x^2+2x-3}{5x-15} \) and simplify your answer as much as possible  
A Rectangular paperboard 12 in long and 8 in wide has a semicircle cut out, as shown below. Find the area of the paperboard that remains. Use the value 3.14 for \( \pi \) and include the correct unit in your answer. |
| 34 |   |
| 35 | Solve for \( x \), \( z = (x - 18)k \) |
| 36 | Find the slope of the line passing through the points (-9, -3) and (-1, 4) |
| 37 | The length of a rectangle is three times its width. If the perimeter of the rectangle is 62 in, find its area. |
| 38 | Evaluate the expression when \( a = -2.5 \). \( a^2 - 4a - 3 \) |
| 39 | Using the sine law \( \frac{\sin(A)}{a} = \frac{\sin(B)}{b} = \frac{\sin(C)}{c} \), solve the triangle ABC with \( A=104^\circ \), \( B=33^\circ \) and \( c=9 \) in, finding \( B \), \( a \), and \( b \). |
| 40 | A seller is planning to offer a new product. The permission to sell that product has a one-time fixed cost of $16,000. The manufacturing cost of the product is $9.50 per item, and the seller will sell the product at a price of $34.50. How many products must the seller produce and sell so that the production cost will equal the money from sales? |
| 41 | Solve the inequality for \( w \), \( -2w - 13 \geq -35 \) simplifying your answer as much as possible |
| 42 | Factor \( x^2 - 14x + 49 \) |
| 43 | Solve for \( t \), where \( t \) is a real number \( \sqrt{t} - 6 = 6 \) |
| 44 | Find the midpoint \( M \) of the line segment joining the points \( A = (6, -8) \) and \( B = (-2, -2) \) |
| 45 | Multiply, \( 7y^5u^5 \times 3y \times 2u^2 \) and simplify your answer as much as possible |
| 46 | Solve for \( x \), where \( x \) is a real number, \( x^\frac{1}{3} = 5 \) |
| 47 | Graph the line, \( y - 2x = 5 \) |
| 48 | Use trigonometric identities to prove the equation, \( \frac{\cot(x)}{\csc(x)} = \cos(x) \) |
| 49 | Solve for \( y \), \( 3(y - 4) - 11 = -3(-6y + 12) - y \) |
| 50 | Set up the problem to be done to find the number asked for in the expression “six less than twice \( \frac{5}{6} \)?” |

Part IV: Demographic and Background Questions

51. Gender: O Female O Male  
52. Age: ____________  
53. Major: ___________________  
54. With which racial group(s) do you identify? (Mark ALL that apply)  
   O African-American or Black  
   O Caucasian or White  
   O Asian  
   O Latino  
   O American Indian or Alaskan Native  
   Other ___________________  
55. Clemson Username (xxxx@clemson.edu): _______________
56. What mathematics course(s) did you take in high school? *(Mark ALL that apply)*

- [O] Algebra I
- [O] Algebra II
- [O] Geometry
- [O] Trigonometry
- [O] Other(s) __________________________
- [O] Precalculus
- [O] Discrete mathematics
- [O] Calculus
- [O] AP Calculus

57. Did you take mathematics course(s) in your high school senior year? 
- [O] Yes (which one)__________________
- [O] No
Appendix C

Participants’ Interview Summaries from the First to the Tenth Participant

Precalc Spring 2014 Student

**Student description:** This is an African American male engineering student with an overall math SE of 6.6 (out of 10). He chose computer engineering mostly based in his interest in computers, but he took some engineering courses in high school and that experience made him consider computer engineering: “I think my biggest influence was in the high school. I took some engineering classes and I liked them, and it kind of helped me pick general engineering.” He failed Precalc the first time that he took it, and he decided to take it the following semester. Despite successfully completing his Precalc course the second time, and being ready to continue taking the math courses required by his engineering major, he did not get enrolled in any college course after completing Precalc.

**High school experiences:** This student had some experience with college-level math courses from taking AP Calculus in his high school. Although he did not report his performance and experiences in his high school math courses, taking AP Calculus in high school may have prepared him to perform well and successfully complete a similar math course in a college context.

**College math experiences:** This student was repeating Precalc at the time of the interview. He failed Precalc the first time that he took it because he did not finish all the prerequisites needed to take the exit exam on time: “Towards the end I had to put back in topics, so I couldn't have all the prerequisites to take the exit exam, and I didn't finish ’cause that.” His ALEKS profile showed that he spent 133 hours working on ALEKS the first time that he
took Precalc, with an average of 9.5 hours per week. And he did not seek help trying to understand the course material and finish on time.

Having a failing experience and retaking Precalc modified this student’s approach working on ALEKS, as he was better prepared to self-pace, and his performance was better the second time that he took the course: “I believe that I'm doing something better, because I'm farther [along in the material] and I'm getting the work better.” He mentioned in the interview feeling more comfortable with the Precalc online material and feeling confident that he would finish all his assignments on time.

Math SE: This student was confident that his math abilities were good enough to complete college-level math courses. He reports a very high math SE (9 out of 10) about completing his current math course with a good grade, and he is confident about completing more advanced math courses after finish his Precalc course. He reports less confidence performing some specific math tasks such as solving math word problems (4 out of 10), showing that he feels more comfortable talking about his math abilities in general, instead of focusing in specific topics like solving homework.

Despite reporting a low math SE for certain math activities, his high overall math SE helped this student to remain confident that he can complete college math courses successfully, even after experiencing some struggles in his first attempt taking Precalc. He is confident about performing math activities in a college context, and he did not report his lack of math competence/knowledge as a limitation for passing Precalc the first time:
Precalc is an online course and you have to do all the work and self-pace, and when I got to the end, I took the assessment and then it [ALEKS] put in topics again that you have to redo and I didn't finish all on time... It’s not difficult, but it’s just try to finish everything before the end.

He is more confident about successfully completing his Precalc course after having some experience working on the same college math course: “I'm retaking Precalc now, because I couldn't take the exit exam last semester. But right now I'm on track to finish it this time.”

**Math competence/knowledge:** Although he spent a good amount of time working in his math course material the first time that he took Precalc, he performed poorly in the intermediate and advanced level topics. According to his ALEKS profile, he completed 40% of the intermediate topics and only 28% of the advanced topics that he was required to finish to be able to take the exit exam (see Table C.1). This poor performance in a non-college-level math course suggests that this student finished his high school with a low math competence/knowledge, even after taking AP Calculus. His performance the second time that he took Precalc was better, improving in all ALEKS topic categories and completing all the requirements to take the exit exam. According to his ALEKS profile, this student completed 68% of the advanced Precalc topics, showing a good basic math competence/knowledge (see table C.1). He was working less time per week on his ALEKS assignments the second time that he took Precalc, with an average of 5.4 hours per week, but he was moving forward at a faster pace.
This student usually uses problem solving strategies that has been related to novice and unexperienced students (Larkin et al., 1980). He uses the surface information of his math problems trying to determine the best way to solve it:

Normally, I go all the way back to the beginning [of the problem] and look to it step by step to see if I made small errors like signs or bad algebra, but other than that I don't think I can figure it out.

Using this novice approach solving math problems could be related to lack of practice or poor understanding of advance math concepts.

Table C.1: Precale Spring 2014 student performance in all ALEKS topic categories.

<table>
<thead>
<tr>
<th></th>
<th>Basic</th>
<th>Intermediate</th>
<th>Advanced</th>
<th>Total</th>
<th>Hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Algebra &amp; geometry</td>
<td>Functions &amp; graphs</td>
<td>Polynomial &amp; rational functions</td>
<td>Exponential &amp; logarithmic functions</td>
<td>Trigonometry</td>
</tr>
<tr>
<td>Fall 2013</td>
<td>71%</td>
<td>40%</td>
<td>28%</td>
<td>56%</td>
<td>133</td>
</tr>
<tr>
<td>Spring 2014</td>
<td>85%</td>
<td>82%</td>
<td>68%</td>
<td>81%</td>
<td>76</td>
</tr>
</tbody>
</table>

**Academic behavior:** This student states that the main reason for failing Precalc the first time that he took it was procrastination, and he does not acknowledge competence/knowledge deficiency as a factor: “Towards the end I had to put back in topics, so I couldn’t have all the prerequisites to take the exit exam.” His poor performance suggest that his math SE was higher than his math competence/knowledge at that time, creating a sense of overconfidence about his math abilities to complete the ALEKS topics easily. The second time that he took Precalc he changed his attitude and work ethic, making an extra effort working in his math material, and asking for help when he was struggling to
understand the math problems. This behavior suggests that his failing experience made him realize that his math competence/knowledge was not as good as he thought before, and the experience helped him to calibrate his math SE closer to his real math competence/knowledge. Matching his medium math SE with his math competence/knowledge helped this student realize that he would need to work harder and seek some help to understand all the Precalc topics this time:

I believe I could master them [Precalc topics] with some help and practice…

Professors can be helpful, and getting help from other students because they are in class with you probably with the same problems.

Failing Precalc was an unpleasant experience, but it helped him realize that he would need to modify his approach working on the Precalc assignments to get better results: “Failing the course made me feel pretty bad, and after that I told myself I will work better the next time, so I can pass it and not have that feeling again.”

His attitude towards getting help in his math assignments is different his second time taking Precalc, which shows a new approach solving his math homework: “If I can't do my homework, then I probably ask for help the same day, so I can figure out how to do it.” He is likely to take advantage of the extra resources available to help him understand difficult math topics when he was struggling, and he is putting more effort to master his math course material: “I've being trying to understand the material more. I've being doing more and finding some better ways to make it easy I guess.”
Math and engineering relationship: He believes that Calculus could be a useful tool in engineering. “You need math 1060 which is, I think Calculus, and other types of math. I think they are very important topics to have [in engineering].” He also thinks that math has an important role in engineering majors in general, but he did not have much experience using math applications in solving real world problems.
Long Calc Summer 2014 Student

Student description: This student is an African American male with an overall math SE of 7 (out of 10). He chose engineering as a major because he likes building things and working on math, and he believes that there is a relationship between these two factors in engineering majors: “I chose engineering because I'm very good with my hands and I love math.” He shows a real interest and enjoyment of school activities since high school, but he seems to like math courses the most: “I have always been good in math... I've always loved them [mathematics]. I've always been one of those people that, I wouldn't say nerd but I really love school.” He has been involved in extracurricular activities like robotics competitions since high school, and that helped him to get motivated to pursue a mechanical engineering degree: “I've also been in different robotics competitions, so I've always picked mechanical engineering because I love robotics, programing, driving, and building.” His real interest in designing and building things comes from wanting to help people to live better and solve problems that affect us all: “coming into work and just try to build something, or build a robot that can benefit or help people in their daily lives.”

Although he is confident about his math abilities and he enjoys working on math activities, he considers math as a challenging topic where he can get confused:

Math, I think sometimes just tries to confuse you because of the way they word things sometimes. So sometimes the difficult part about a math question is just trying to know what they want in general.
Despite the challenges that math courses may offer, he considers math struggles as an opportunity to prove himself and show he can master difficult topics and achieve great things with his education:

In math there is straightforward answer, you want to get the right answer and if you get the right answer you feel pretty good and proud of yourself, and that was always me so I love math for that.

**High school experiences:** This student’s medium math SE was supported by his good performance in high school math courses. He took AP Calculus and performed really well on his final test, and this successful experience in a college-level math course contributed to his love of math: “I took AP Calculus my junior year, and I took the AP test at the end, and I actually got a 4. So I was happy about that grade.” His math preparation before college seems to be good and he reports having been successful in all his high school math courses and activities: “I have always been good in math.”

He showed interest in extra class academics programs such as sports and robotic competitions, and being successful designing robots fueled his interest in engineering:

I was in a program called "Robots, Math, and Science." And we did a bunch of robotics competitions. I won first place in 2 out of 3 of them, so I was very interested in robotics… I love math, and between mechanical engineering, or civil, it was always engineering.

Although he is very confident about his academic skills and good work ethic, he believes that some of his peers may have stronger math skills and academic preparation due to their
access to high schools with better academic programs. He reports coming from a small high school with some academic deficiencies, and that made him feel less prepared than his peers to learn complex topics:

My weakness is my background. I hadn't come from a prestigious high school or middle school, and that's why some people have advantage over me and I try to catch their back basically… I guess there are people that are more experienced than me.

**College math experiences:** His experience taking college math courses made him realize that math courses in college are more difficult than high school math courses, but he remains confident that he can perform well if he putted enough effort and hard work to learn advanced math topics:

I feel like things [math courses] are getting harder sometimes, but as long as you want to learn, and you want to get better then you can do it. And I've always loved math so I always try to be better at it.

Coming from a small high school made this student start his college math courses with the support of the Mathematical Excellence Workshop (“MEW” program). The MEW program was offered by the university to support students coming from underrepresented groups or lower academic level high schools:

I probably work about 13 hours a day [on math activities], because right now I'm in the MEW program and I’m taking math classes, seminars, and symposiums, and I always try to be involved in math. With this program if I can't solve homework I
can go to ask my friends, and we have, also, a study hall late at night, so I can ask my tutors some things.

Having extra resources available to help him in case he struggles working on his math material made him feel really confident about completing his math courses successfully: “I have the help when seeking advice of people around that know, so I feel pretty confident that I can get A’s and B’s.”

**Math SE:** His math SE was medium (7 out of 10) and he reports being very confident about performing well in his math courses is college (9 out of 10), showing a high math SE in performing math in general. His math SE was lower for certain math activities that are especially difficult for him, like solving math word problems or graphs (4 out of 10):

I never like graphs honestly, I'm big on numbers so I probably say a 4 [math SE level]. Graphs help to solve problems so that’s a bad thing, because you are going to need them in the real world.

Despite his struggles with some specific math problems, he is aware of the importance of hard work trying to overcome his math deficiencies and improve his math abilities. His overall math SE seems to be high enough to make him feel confident about trying to get better at these challenging math topics:

The seminar tries to deal with the real world problems, so I can actually get better at the difficult word problems that I said before… I probably could work a little harder. I'm trying to do great things with my education.
Math competence/knowledge: This student’s math competence/knowledge was difficult to track due to the lack of performance information in summer semesters. He passed the Long Calc course during the summer, and he enrolled in Long Calc II the following semester where he received a 91 as a final grade. He also completed Calculus II during the Spring 2015 semester and he got an 87 (see Table C.2). His good performance in Long Calc II and Calculus II was considered as evidence of high competence/knowledge for the Long Calc course, and his Long Calc II final grade was used as an indicator of competence/knowledge for the summer 2014 semester.

Despite showing good basic math competence/knowledge he pointed out that he sometimes struggles with specific topics like math word problems:

If you give me a math problem or a math equation I’m probably going to solve it for you. But when it came to word problems, like long word problems trying to figure out different aspects about those word problems, I just could never get it... but that's one thing I hope can change, hopefully.

He normally looks for help when he cannot understand a problem or any hard topic: “If I'm wrong, then I just try to talk with somebody and find what was wrong and tell why I get the answer wrong.” He normally thinks ahead about a math problem’s solution and then he compares that guessing with the final answer:

Sometimes when you do math… you kind of think ahead about what kind of answer is going to be, and if it doesn't look like that answer that's when you start questioning yourself.
This strategy shows some experience and a strong ability to solve math problems (Larkin et al., 1980), and it facilitates the learning of advanced math topics (Gick, 1986).

Table C.2. Long Calc Summer 2014 student performance in his college math courses.

<table>
<thead>
<tr>
<th>Term</th>
<th>Course</th>
<th>Course average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2014</td>
<td>Math 1070 (Long Calc II)</td>
<td>91</td>
</tr>
<tr>
<td>Spring 2015</td>
<td>Math 1080 (Calc II)</td>
<td>87</td>
</tr>
</tbody>
</table>

Academic behavior: His math SE was lower than his math competence/knowledge at the time of the interview. He showed to have good math skills and some successful experiences with college-level math courses before college, but his math SE is not as high as it should be according to his good math preparation and prior success in math courses. Although this student was hesitant about his math skills and preparation to successfully complete college math courses, he showed high confidence in having a successful academic experience at college math courses. Despite the gap between a lower math SE and his math competence/knowledge, his math SE is high enough to keep him motivated to participate in math activities, and work hard to take advantage of every opportunity to improve his math abilities:

When you come to college, teachers aren't going to check your homework so it is up to you to do your homework. It is really an option, it's not really mandatory but optional, but I feel that you should always take every advantage to understand the material.

He also found all the extra class resources available at the MEW program as valuable opportunities to improve his math competence/knowledge, and get as much help as possible to improve his math skills: “With math there is definitely a right answer and if you
are not getting it, hopefully you can with people’s help.” He considers that working with other people’s help would be useful in his college education and later in his engineering career: “To be an engineer you have to work with other people.”

He is confident about learning difficult math topics. Even when he struggles to understand some math problems, he remains confident that he could solve them if he tries more than once, and looks for others’ help to understand his math material:

If my way is just not working at all, then I go back and seek help from people that I know have the means to give me the right answer, or tell me how… I like to ask everybody between teachers, tutors, other classmates or even friends I had in class before.

Math and engineering relationship: This student understands the importance of math abilities in the engineering designs. He considers Calculus an important tool for engineering and he thinks that math could help develop a better understanding of engineering concepts:

You need [to become an engineer] definitely mathematics and science and… you definitely need Calculus classes or courses in order to understand the graphs, the concepts or engineering skills.

He is aware of the importance of developing good math skills to be able to solve real life problems using engineering designs in a safe and efficient way:
In math if you get it wrong it’s wrong. And like you said in real world problems if it’s wrong, it could hurt more than just me; when you are wrong you can hurt other people. So in math engineering you always want to be right, or try to be.
Student description: This student is an African American female. Her overall math SE was high, reporting a 7.6 (out of 10). She became interested in mechanical engineering after her experiences in summer camps and some high school courses: “[In summer camp] they took us to the pitch shop, and they taught us how to change tires, and how to get into NASCAR, and since then I was like I love NASCAR! I was I believe 7.” Her passion about NASCAR was the most influential factor to choose engineering as a major, and she really wants to be involved with engine design: “NASCAR is my favorite sport and I want to go and race cars, and build engines with the mechanical engineering.” She really wants to get a job as mechanical engineer, but she thinks that she may have some troubles getting that type of job because she has seen that engineering is a predominately male field: “It’s [getting a mechanical engineering job is] going to be difficult because you don't see a lot of women [as] engineers.”

She believes math courses are not especially hard for her, and she had some good experiences learning math before college which helped her build a high math SE. She also believes that math is an important topic that could help people to solve everyday problems: “Math courses in general they are not bad. I can deal with them. You need math in whatever you do, is not just engineers is like every day.” She considers engineering majors to be challenging, but she is highly motivated to complete her degree due to her interest in designing and building engines: “I'm going to get paid to do what I love, it's going to be hard but… it's going to be fun at the end.”
High school experiences: She did not take any college-level math course at her high school and she decided not to take Calculus to avoid extra work in her last semester, which suggests that she is aware that Calculus is an advanced class and it could be difficult: “I took Precalc, Geometry, Trigonometry, Algebra II on the 8th year. I took Precalc and they want me to take Precalc and Calculus but, I was like, it was too much.” She performed well in her math high school courses, and she also completed some honors courses where she reinforced her math SE: “Math, I was good in high school and did honors courses with math and stuff, so it was hard but I was like I’m going to get it and I did pretty well.” She mentioned that her high school math instructors were always supportive, but she had a bad experience with one instructor that taught her class in a fast pace:

I had one class my sophomore year, she [the instructor] moved really really fast. She taught a section a day, and gave you homework to force you to say you knew it… and she just kept going.

This fast-paced teaching style affected her performance in the course and also changed her perception about math courses’ difficulty: “It [math course] was like full of big problems. That would be hard for me, I don't think I want to face that again.”

College math experiences: She is confident about completing Precalc successfully: “I feel pretty confident and if you are asking me right now I'm doing pretty good.” She chose to start in a Precalculus course to refresh her math competence/knowledge before trying more challenging math topics like Calculus:
They want to put me in Calculus but I was like, no let me refresh myself and take Precalc again. ‘Cause I don't want to go and not really remember stuff. I just needed to refresh my mind because I didn't practice [math] since early December.

She was confident about her basic math preparation to complete a review course, but she was aware of her lack of practice doing math and her poor experience with college-level math topics.

Although she has never had an online course before, she states that the ALEKS software explained all the topics in a detailed way and that helped her to understand the material:

Even though it’s straight on the computer [Precalc] and is nothing else instead of the TA to help you… they explain step by step in the video. They show me so I can write the problem down and do the next one from there so it helps a lot.

She was comfortable self-pacing her math course using ALEKS, and she states spending a lot of time working in her math assignments:

You have to do it [Precalc assignments] on your own time. She [Precalc instructor] said that you must to put at least 10 hours a week of your own time to do it, not in class or you won't pass it.

Although she mentions that she was working hard and putting a lot of time to practice math, her ALEKS profile shows that she spent less than 5 hours per week practicing problems. Her performance at the end of Precalc was poor, and she failed it. She took Precalc again the following semester and she also failed to complete all her math assignments the second time she took it.
She is very confident about finishing all her math courses and getting her engineering degree. She is aware of the work and challenges involved in pursuing an engineering degree, but she is motivated to work hard and put extra effort in her academic activities:

I know it’s going to be harder from here, it's nothing easier from here, it’s very difficult now… the homework that she [Pracalc instructor] gives us is kind of insane. I’m normally done with my classes by 12 so I'm at the library doing work or in my room doing work with a friend. I do work at least an hour a day, at least one hour per day for math class if not more.

Although she mentions that that engineering is considered a predominately male field, she feels that she can perform as well as her male peers in engineering and math activities. She reports having some bad experiences working with her male peers in college, where they have tried to undermine her just because she is a female student:

I guess because I'm a female they expected you to not know, and they underestimate you. But you have to surprise them sometimes and show them that you know as much as they do… In engineering classes it’s predominately men so they don't ask the girls.

She is confident that she can perform as well as any of her male peers so these issues did not affect her performance or her confidence about her abilities:

We [females] are doing engineering like you [male classmates] are, we have to learn the same things, we understand this; let’s help each other. I can help you and if you listen, you can help me out, we can go together.
Math SE: This student reports high confidence in her math abilities, especially for completing Precalc which was considered a review for her:

I think it increased [my confidence to pass math courses] when I got here [college] because I realized I’m paying for this education and it’s not free anymore… [college instructors] they are not going to specialize sessions for you so yeah it increased, it did tremendously.

Her confidence finishing her math courses is based in her prior success performing math in her high school, but she is concerned about the consequences that failing college courses could have for her and her family. She is very confident about passing Precalc at the time of the interview, and she is feeling comfortable self-pacing and taking the online course: “I feel pretty confident I can pass it [Precalc] instead of reading books the whole semester.”

She reports a lower math SE (6.5 out of 10) for specific math activities that may be challenging for her, such as solving math word problems, or applying math to solve engineering problems; but she reports high confidence in her math abilities in general. Despite reporting high math SE for math in general, she considers math a challenging topic that is getting harder in college math courses: “In math I feel like there is endless concepts, there is no end with it.”

Math competence/knowledge: According to her performance in her first Precalc course, this student’s math competence/knowledge coming from high school was low. She struggled to complete her Precalc assignments, completing only 15% of the requirements to pass the course (see Table C.3). She acknowledges that some math topics were very
challenging for her: “Sometimes I'm just like, I can't get this math!” And she struggles with some basic math topics; she completed 47% of her basic math assignments (see Table C.3). Her high math SE helps her overcome her math deficiencies; she spends extra time trying to get better math skills, but her problem solving strategies are very basic (Gick, 1986):

I learned to underline stuff, and know what I need [to solve the problem]. I write the whole problem down and then, break it down into sections, and I think on what I know and what I don't… I don't think ahead of the answers.

Trying to solve problems based on the surface variables of the problems suggests poor understanding of the math concepts and applications; and these problem solving strategies have been related to unexperienced students (Larkin et al., 1980).

She usually feels anxious performing tests, and that could affect her grades and performance in general: “I may freak out when I study for a test. I freak out because tests scare me.” But her ALEKS profile shows a poor understanding of the basic math topics, suggesting that she was not ready to take a college-level math course.

Table C.3. Precalc Fall 2014 student (1 of 2) performance in all ALEKS topic categories.

<table>
<thead>
<tr>
<th></th>
<th>Basic</th>
<th>Intermediate</th>
<th>Advanced</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Algebra &amp; geometry</td>
<td>Functions &amp; graphs</td>
<td>Polynomal &amp; rational functions</td>
<td>Exponential &amp; logarithmic functions</td>
</tr>
<tr>
<td>Fall 2014</td>
<td>47%</td>
<td>0%</td>
<td>0%</td>
<td>15%</td>
</tr>
</tbody>
</table>

Academic behavior: This student is putting extra time to complete her Precalc assignments and keep up with the class pace: “I think every day at least an hour, an hour everyday makes me stay on top of it [Precalc assignments].” Although she mentions working hard and having
a good attitude towards her Precalc course, her interview responses do not match her ALEKS profile. She performed poorly at the end of Precalc, completing only half of the basic math problems. She reports a high math SE and she is confident that she would successfully complete all her college math courses, but her low math competence/knowledge caused her to struggle to complete her ALEKS assignments.

Having a high math SE helps this student to try to get help and look for extra supports that could help her improve her math abilities: “In my class, if I have people there to help me I will use them. They can explain me or something, they can show me. If they are there for a reason why not use them.” The apparently big gap between her high math SE and low math performance/knowledge did not discourage her to keep trying to improve her math abilities, even after failing her first Precalc attempt. She is likely to ask for help if she is struggling to solve challenging math problems, and she uses all the resources available to improve her math abilities:

I found my tutor and go to them, I go to RISE tutoring… I go with my sister sometimes… Yeah I call people to help me… I mean somewhere must be a tutor; somewhere someone understands. If I second guess myself about it then I know that I need to ask someone.

She considers hard work and practice important factors to get better math skills: “Homework is very useful… some knowledge comes with extra work.” Even though she reports a good attitude and work ethic in Precalc, her low math competence/knowledge is a problem that she could not overcome. After failing to improve her math skills, and close
the gap between a high math SE and low math competence/knowledge, she decided to stop taking math courses in college and after 3 semesters she left the university.

**Math and engineering relationship:** She relates good math skills with a good performance in engineering and designing engines:

Math skills! I need to know [to become and engineer] like equations and how to convert one set of measurements to others and how to draw sketches… I need to know how to transfer the volts, and amps, and stuff, so I know not to overcharge the battery.

She knows that math is important for engineering students, but she has a poor understanding of the math applications that can help her solve real life problems with technological solutions.
Precalc Fall 2014 Student (2 of 2)

Student description: This student is an African American female with an overall math SE of 8 (out of 10). She chose electrical engineering because she thinks that she is good at math and she finds this ability important for completing an engineering degree. She was taking Precalc at the time of the interview, and she failed the class because she was not able to complete all the course prerequisites to take the exit exam at the end of the course. This course was her first math course in college, and she is aware of the issues that failing her Precalc course would bring her in the next semesters. Despite her early struggles with college math courses, she is confident that her math abilities would be good enough to complete all the math courses required by his major. She believes that math knowledge comes easier for some kind of people, and she considers herself as a math person with good math competence/knowledge, and the ability to understand math faster than her classmates:

Not everyone will probably understand math as easy as other people. It’s just how I see it, some people are math people, other people are English people, and yes is just based on your understanding… math is easier for me.

High school experiences: She took some non-college-level math courses in high school, and she choose not to take a Calculus course during her senior year. She decided to avoid taking Calculus because she already had all the math credits required by her high school, and other classes were better for her plans in senior year:
In my high school I took Algebra in middle school, then Algebra and the Geometry, and I take Precalculus in... I was about to take Calculus but I didn't want to ‘cause…

It was senior year so the last classes I took were better for what I was looking.

She was very confident about her math competence/knowledge, and she was not scared about the idea of taking Calculus in high school. She liked her high school math courses, but the teaching style was a big influence in her perception about these course and performance:

I loved Precalculus. I had a teacher who taught it real well. Then when I switched schools, I had a teacher that was terrible as a teacher, so I didn't want to take it again that year. But Precalculus, for the most part, I liked it.

Struggling to understand her high school Precalc teacher did not change her perception about math in general, and she remained confident about her math competence/knowledge.

**College math experiences:** This student struggled to complete all the Precalc web-assignments on time. She was behind schedule with her math assignments when the course was about to finish, and she failed to complete them on time. She did not mention lacking good enough math competence/knowledge as a reason for failing Precalc, and she blamed other factors such as the online format, or not knowing the assignments’ due dates correctly:

I didn’t know that the cutoff day was so early, or I would’ve found a way to finish [Precalc assignments]. I can't take the test because I didn't finish with the objectives,
so now I have to take the placement test again and try to place on Calculus I or Long Calc.

She reports spending less than six hours per week working in her math assignments, even after being told by the instructor that they should spend at least ten hours per week working on their Precalc material.

The Precalc course online format was something new and difficult for her. She usually feels more comfortable when a instructor is teaching the class and she has someone ready to help her in case she does not understand something:

It’s not hard, is just the amount of material, and sometimes the computer gives you an example and you are trying to understand what the computer is saying, and trying to teach you, and that's kind of hard… It is easier for me having a person to teach me.

She also struggled with the way that ALEKS evaluated her math work due to the lack of customize feedback about her mistakes, and that usually frustrated her: “Sometimes when I don't know the answer and I just can't get it right and I just keep getting the answer wrong and wrong on ALEKS... yeah those problems would stress you.” She did not report feelings of stress when she was working on math problems, but she is likely to get frustrated and stop working if she struggles to get the right answer, especially when she is learning something new using the online software and there is no one to help her:

I think is just harder on the computer, and then, um, trying to do a lot of the objectives in the time frame that you have is like way more, I don't know harder.
Because you have to do like a lot of hours during the day just to finish it. I don’t know and sometimes you can spend like 2 hours on just one topic.

Math SE: Her overall math SE is high (8 out of 10), especially when she talks about completing all her math courses at college. She is very confident that her math competence/knowledge is good enough to learn and understand complex math topics like Calculus. Despite this high overall math SE, she reports a lower math SE level in some specific math tasks where she is struggling. She is especially concerned about her ability to master all the Precalc material due to the big amount of information, reporting a math SE of 5 (out of 10) for that particular task: “I think once I get out of Precalc I will be able to finish all of them [all math courses for her major].” This low Math SE when she talks about her online math course is different from her Math SE level talking about performing math in general. She believes that math comes easier than other topics for her, and she is confident that her math competence/knowledge is good, even after failing his Pracalc course: “I really understand it, I can get the math faster than the other subjects, and I did math earlier in high school. I finish math before others so yeah I just like it.”

She is confident that she will be able to take the CMPT again and score high enough to take Calculus the following semester: “I should be able to get a better score [on the CMPT] now that I went through more topics than when I was taking it during the summer. So I’m confident now that I can get that score.” Her Math SE did not change after her failing experience taking Precalc, and she remains very confident about her math competence/knowledge after having some practice time to refresh it. She did not take math courses in her high school senior year, and she feels like she can recall more math topics.
now: “It's [my confidence taking the CMPT] higher because I worked more thorough the programs and I can remember most of the stuff now… I know I will score higher.”

She is confident that she can solve math problems, and she thinks that her mistakes working these type of problems are normally minor errors that can be corrected easily if she reworks the problem: “If my answer is like false, it's usually like the simple things that shout me out. But I think I would be able to figure it out for the most part.” She also reports a high math SE when she was asked to solve the math test in the interview protocol, which supports her confidence in her overall math competence/knowledge.

Math competence/knowledge: This student was placed in Precalc and she struggles to keep up with the pace and remember all the topics that she needs to know to complete her Precalc assignments:

I don't remember some of that stuff [Precalc topics], maybe the ones I'm doing now, I remember those topics but the ones for before maybe not. I can see a problem and think, I remember this problem but I can't remember how to do it.

Her Precalc performance is deficient, especially in the intermediate and hard topics of the course (see Table C.4). These poor results in Precalc reflect a low math competence/knowledge and suggest a lack of practice and experience solving math problems.

She normally struggles learning new math topics, but her confidence solving these new math problems normally increases once she has the time to practice and gets helped: “Maybe the hardest thing would be like learning it the first time, and try to catch on to it,
that may be hard. Once I figure it out, I would be able to work it.” Doing homework is also challenging for her, because sometimes she cannot remember what to do and there is no one to help to solve her doubts: “When I'm doing homework is just like... I can't remember what I did and I have to wait or go back to my notes and then try to remember.”

Table C.4: Precalc Fall 2014 student (2 of 2) performance in all ALEKS topic categories.

<table>
<thead>
<tr>
<th></th>
<th>Basic</th>
<th>Intermediate</th>
<th>Advanced</th>
<th>Total</th>
<th>Hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Algebra &amp; geometry</td>
<td>Functions &amp; graphs</td>
<td>Polynomial &amp; rational functions</td>
<td>Exponential &amp; logarithmic functions</td>
<td>Trigonometry</td>
</tr>
<tr>
<td>Fall 2014</td>
<td>77%</td>
<td>11%</td>
<td>0%</td>
<td>29%</td>
<td>88</td>
</tr>
</tbody>
</table>

Academic behavior: This student is very confident about her math competence/knowledge: “I really understand it, as I can get math faster than the other subjects.” This high Math SE is reflected by her enjoyment of math courses, good attitude towards math related activities, and great confidence on completing all the required math courses to get her engineering degree. This student’s math SE is greater than her competence/knowledge coming from high school. This gap makes her feel overconfident about her math competence/knowledge, which leads her to procrastinate and underestimate the value of hard work at math courses: “Maybe if I had put a little more time on it [Precalc], then I probably would have finished.” She realizes that she was falling behind in her Precalc assignments and she did not make and extra effort to finish on time, thinking that she would have time to catch up the course’s pace later: “Sometimes I get behind. If I feel like I'm getting too behind, then I try to do more hours and get more objectives.”
She does not mention a lack of math competence/knowledge as a reason for failing Precalc, even when she states that she sometimes got frustrated for struggling to understand and complete some assignments:

When I get frustrated to ALEKS or with a certain problem, then I stop doing it for a little while. And then I come back to it because it would be stressing if I just keep doing it wrong.

She usually stops working in her math activities if she faces struggles and there is no one to ask for help. She does not quit the activity completely, but she does take a break and she retakes the activity another day. Although she recognizes the value of practicing when learning math, she states working few hours per week in her math assignments, considering that she would be able to finish later during the semester:

Maybe if I had put a little more time on it, I probably would have finish. Yeah I will say that… I think I put a good amount of time for it, but I guess the time for ALEKS is more time than I actually have. It’s just easier to just like put it off, like OK I'll just do this tomorrow.

The overconfidence of this student about her math abilities and the gap between her high Math SE with a lower math competence/knowledge made her procrastinate and let the time pass by. She thinks that she can recover the pace easily during the semester, and she realizes that she will not finish on time if she got really behind.

This student is likely to ask for help when she has difficulty understanding a math topic, and she always shows a good attitude towards math activities despite her failing
experience: “If I don't understand the exercise, I would go ask the teacher and tell them that I don't understand it, and try to make them to explain it to me or something.” She seems to need the instructor’s help to learn and practice new math topics and solve doubts in case she struggles, and she usually uses the help of extra class resources such as tutoring and office hours: “I would try to meet a tutor to, you know help me understand it more, or maybe the professor during their office hours and try to work it.” She always shows confidence in her math abilities, and how that math competence/knowledge would be enough for finishing all the math courses required by her major.

Math and engineering relationship: This student decided to pursue his current engineering major based on her perception of her good math abilities: “Most people say that engineering is basically with math and science so I said, OK well I'm good at math so I probably will be good at this too.” Although she considers math as the most important ability to become an engineer, she shows poor experience trying to connect math competence/knowledge to engineering tasks and problem solving.
Long Calc Spring 2015 Student

**Student description:** This is a white male civil engineering student with an overall math SE of 6.2 (out of 10). This student was interested in civil engineering and the designing part of this major. His biggest influence for choosing engineering as a major was a high school friend that wanted to become a civil engineer; this friend convinced him to take some engineering courses in high school and he enjoyed taking those courses: “I did have a friend in high school who wanted to do civil engineering, so we were in the same classes together and that was like oh men this is really fun.”

He is taking Long Calc for the second time after failing his first attempt the semester before. His math SE decreased when he started taking college math courses due to his perception of the higher academic level in college math courses compared to the low academic level of his high school. Despite feeling less confident about his abilities to perform well in college advanced math courses, he remains confident enough that his math abilities would be good to complete these math courses, even if he struggles to keep the pace and understand some advanced topics. He thinks that all kind of people could improve their math competence/knowledge if they practice enough, even if there are some people with a natural talent for learning math that learn math topics easily: “If you work hard you can do better than the people with natural talent. You don't need to be special in math. If you practice enough you can learn the most difficult math.”

**High school experiences:** This student was very confident about his math abilities in high school, and he decided to test his math competence/knowledge by taking the hardest math
course offered in his high school. Even after his experience taking AP Calculus, he did not feel ready to take a college-level Calculus class as his first math college course. “The last one [math course] I took was AP Calc. So when I came here I was like, ok let's take the highest class I took in high school and take one below, yeah and that's why I took Precalc.”

His perception about his math abilities was affected by the poor academic level in his high school, where he took Algebra, Precalc, and Calculus. He did great in these math courses, but he states that his instructors help him a lot, teaching him easy material in a very slow pace:

The high school I came from, you can sleep in class and still make an A. I left out of my Calculus class with a 104. I'm telling you it was really easy, it was horrible… high school basically held my hand the whole way.

This student’s high school experiences helped him develop a high math SE, but he was aware that his math competence/knowledge had some deficiencies when he took the AP Calculus test and did poorly, scoring a 2 out of 5. Even after his poor performance in the AP Calculus test, his math SE remained high, especially for specific tasks like solving derivatives: “it was a yearlong class, and we spend half a year on derivatives, so I really got good at that.”

College math experiences: This student scored high enough to be placed in a Calculus course in his CMPT test, but he tried to be cautious about his transition from high school math courses to college math course, so he decided to start in a course below the Calculus
level. He felt that his high school academic level was not very good, and that made him believe that college would be different and more difficult:

I did make a high enough score to do it [take Calculus], but I just cowered to take the math thing like easy because my high school was really easy; and Clemson was like three times harder than that, so it was like ok I'll just learn the Clemson way and then I'll move up from there.

He failed his first Long Calc attempt; he struggled to understand some advance math concepts that he has never learned before. Even after realizing that college math courses were more challenging than his high school math courses, he does not show interest in spending extra time working to improve his math deficiencies and pick up the class pace: “I just didn’t put enough effort into it [Long Calc]… I just had to relearn everything. The information here is a lot different, so that kind of trip me up.” After his failing experience taking Long Calc the first time, he remains confident about his math abilities and he states that the main reason for failing the course was his lack of effort. He also mentions that the teaching style could be a factor in his math learning, blaming the instructor’s teaching style for his lack of understanding in some Long Calc topics:

She was kind of fast at some points and then, she skips something that you would find on the test, or she would go over one thing vaguely and then do it really fast, and I couldn't keep up.

After his failing experience, he took Long Calc again the following semester; he was doing better at the time of the interview. He is working harder and he states that he
was spending around 5 hours per week working in his math assignments. He usually studies on his own to improve his math abilities, and takes extra time getting ready to take a test:

If there is an exam, I set like 7 days in advance, um probably an hour and a half a night. Now I kind of just study by my own, I mean I still going to the class but that's how I study now.

He assimilates the differences between his high school and his college math courses in a good way, recognizing the importance of hard work and practice trying to successfully complete a college math course. He shows a different approach for his Long Calc course the second time he took it, showing a better work ethic and attitude that helped him perform better and take responsibility of his own learning: “I was like, ok I can't blame them [math instructors] anymore everything is on me now.”

Math SE: He shows great confidence about passing Long Calc, but this high confidence is mostly based on his new approach taking the course. He is working harder than the first time he took the course, and he is using his failing experience to realize that he would need to put more effort to be able to complete his college math courses: “Yes, I can pass it [Long Cal]. I'm putting a lot more effort into this semester than I did last semester.” Math used to be his favorite topic, but that change when he came to college. He realizes that college math courses are more difficult that he originally thought. This realization caused his math SE to decrease and it changed his perception about math courses: “Math used to be my favorite subject before I came here. Now my favorite subject is engineering.” Failing his first Long Calc attempt helped him realize that he was having some math
competence/knowledge deficiencies, and it helped him develop a better estimation of his math SE beliefs compared to his real math competence/knowledge. After adjusting his math SE closer to his math competence/knowledge for a college context, this student’s math SE remains high enough to make him feel that he can complete all the math courses required by his major. He is confident about passing his Long Calc course now that he had some college experience and practice:

I’m very confident. Since I took it last semester [Long Calc], I feel like I’m just going to breeze by this class now. I know mostly everything he [the instructor] is going to cover… Last semester 5 [level of confidence out of 10], this semester 9.

He describes different math SE for specific activities, reporting lower math SE for activities such as long word problems and graphics. He reports a higher math SE when he talks about performing math in general, instead of working on specific math problems, despite reporting low confidence solving some type of problems: “I have a problem with the epsilon delta stuff. I mean I understand those, it’s just the graphing part where I struggle.” He is confident that he can understand these challenging problems if he makes and extra effort. He is confident about passing his following math courses, but his confidence decreased when he was asked to get a grade of B or higher in those courses. He believes that his college math courses are going to be very challenging, and that causes his math SE to decrease:
In high school you can sleep through your classes and still make an A. Over here you have to put effort... Of course it have changed, my confidence was like 10 or 11 in high school to like I said probably a 7 now or 6.

**Math competence/knowledge:** This student’s performance in his first Long Calc course was almost good enough to pass the course the first time. His grade was 67 (see Table C.5), which was 3 points short from the passing grade (70). His performance improved the following semester, and he finished the Long Calc course with a passing grade of 73 the second time he took it. He took Calculus II after finishing Long Calc, and he did poorly, obtaining a 39 as his final grade. He decided to take Calculus II immediately after his failing experience, and he was performing better with a grade of 80 after the first two tests (see Table C.5). This student’s performance suggests that his math competence/knowledge is good at a basic level.

He normally tries to redo everything one more time when he struggles solving a math problem, looking for minor mistakes in his math equations: “I completely redo the problem to see what was wrong.” He usually uses the problem’s surface information to choose the best equation to solve it, suggesting that this student lacks experience solving advance math problems (Larkin et al., 1980):

> Probably the hardest thing will be identifying what I need and what I don't need, because sometimes you just put things that you don't need in there... If there is big numbers [in a math problem], I expect a big answer.
Table C.5: Long Calc Spring 2015 student performance in his college math courses.

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<th>Term</th>
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<tbody>
<tr>
<td>Fall 2014</td>
<td>Math 1040 (Long calc)</td>
<td>67 (Failed)</td>
</tr>
<tr>
<td>Spring 2015</td>
<td>Math 1040 (Long calc)</td>
<td>73</td>
</tr>
<tr>
<td>Fall 2015</td>
<td>Math 1080 (Calc II)</td>
<td>39 (Failed)</td>
</tr>
<tr>
<td>Spring 2016</td>
<td>Math 1080 (Calc II)</td>
<td>80 (not final)</td>
</tr>
</tbody>
</table>

**Academic behavior:** This student took his failure experience as an opportunity to align his math SE with his math competence/knowledge. Having a more realistic perception of his math abilities made him realized that he would need to work harder and look for extra help outside his class time like tutoring and supplemental instructions: “I’m putting a lot more effort into this semester than I did last semester.” He is aware of the importance of working hard and looking for extra help when he is struggling to understand a new math topic: “If I don't understand it [math problem], I'll probably go to tutoring or something and then my confidence will go up.”

Despite his failing experience and difficulties adjusting to the college-level math courses, this student remains confident that his math abilities would be good enough to complete all the math courses required by his major if he works hard. He is aware that math courses would be more difficult each year, and more math courses will be needed to complete his engineering: “I know that it’s [math] going to be harder each year. I’m just going to work harder each year, I'm going to work smarter.” Getting help to understand new math topics and resolve doubts while he is practicing math is very important for this student, and he feels more confident about his math abilities when he understands his math instructor’s teaching style: “I would need a lot of practice, and someone that knows what he is doing and he can show me the steps to get the answer.”
This student is expending extra time working in his Long Calc assignments, but he is likely to give up if he started struggling with a difficult topic and there was no one to ask for help. His confidence in his math abilities normally decreases if he struggles to understand a new topic: “If I got two different answers and then both are wrong, then it [confidence solving a math problem] drops to 3 [out of 10].” But he seems to be likely to ask for help before giving up: “I'll try as many times as it [math course] takes me.”

Math and engineering relationship: He is aware of the importance of problem solving skills and how numerical mistakes in these problems’ solutions can result in tragedies: “You don't want to give the wrong units and kill everyone.” Despite his understanding of the importance of and engineering work and calculations, this student does not relate good math abilities with engineering majors. He mentions problem solving skills as very important for engineering, but he mentions that only very basic math applications are needed to solve engineering problems: “A lot of algebra is in engineering because you have to rearrange problems.” He had a poor understanding of the math applications that could help him solve problems, and that makes him believe math courses are just another course that he must to complete to get his degree: “You have to get your math and other stuff out of the way. They are part of the classes that you are required to take before you can get your diploma.” He did not find much worth in math courses, thinking that engineering majors try to teach you more than you really need to know to become a good professional: “Engineering kind of teaches you most than you need to know.”
Precalc Spring 2015 Student

Student description: This is a white male engineering student with an overall math SE of 6.8 (out of 10). He decided to pursue a computer engineering major influenced by his high school friends’ interest in engineering: “I heard about engineering from some friends and I just look into it and I was like: ‘This sounds like something that I would like.’” His medium math SE is well supported by good experiences taking math courses in high school. He is confident that his math competence/knowledge is good enough to help him complete his college math courses: “I feel pretty good about passing that [math course]… I already kind of know what to expect.” He believes that learning math could help him develop better abilities to think of innovative solutions to all kind of problems and become a smarter person:

I just like math because doing it makes me feel smart. When I learn a new math concept and I get it, I feel like my intelligence has increased, as opposed as oh I just know this as a fact.

He enjoys the challenges of learning math, even when he has had some failure experiences in math courses and has had to learn new, difficult topics in college. He thinks that overcoming difficulties is part of the learning process in math courses and people should not be intimidated by that: “We need to show them [people struggling with math] that math is not scary, and they have to think about it, and try to enjoy the challenge of it.”

He thinks that math instructors and departments use a poor approach to teach math courses, even when these math courses are important in students’ development. He believes that math instructors sometimes make math courses seem very difficult and intimidating,
making students feel that these courses are just “weed out courses” that would determine who is ready to continue with their college education:

The way it's [math] being approach is shoving out so many people. There's like all that research and data that show that a lot of people are intimidated by math, they look at math and they think this is scary.

He acknowledges that math courses could be hard and challenging, but he is confident that his math abilities are good enough to tackle that challenge, even when he knows that college math courses will be harder than high school math.

**High school experiences:** He took a math course every year of his high school, including a Calculus course in his senior year. Although taking a college-level math course in high school is a good opportunity to develop good math skills, his experience taking Calculus in high school was not what he expected because this course was a combination of trigonometry and a brief introduction to basic Calculus concepts. He feels that the way that the math course was taught in his senior year in high school was not good enough to prepare him to start a college-level math course: “At my high school, I was introduced to trig and I was introduced to Calculus, but I didn't get a good foundation for either.” His high school was offering more advanced math courses during his senior year, but his math instructor did not let him take those courses even when he was confident that he was ready to take a more advance math course: “I wanted to push to the more advanced math but the teachers didn't let me, even though I had a decent grade.”

**College math experiences:** His first math course in college was Calculus I. He did score high enough in his CMPT to start in a college-level math course, but he decided to
withdraw after some difficulties understanding the instructor’s teaching style and struggling to keep up with the course pace: “I did Calculus I when I came here and I actually had to withdraw from it. Because I guess the teacher, the way he taught it was really weird.” He blames the instructor’s teaching style for his struggles on his first college math course, where he was doing poorly before withdrawing. He reports scoring a 40 on his first test and struggling to keep the course pace: “I just cannot keep up with this [Calculus I]. It was kind of weird because of the teacher I had, it was his first year and he definitely did not have, like, good teaching abilities.” This student’s college advisor suggested him to withdraw Calculus I to avoid a failing grade in his record. He considered withdrawing a good idea to refresh his math knowledge taking a lower level math course, aiming to practice and learn the Precalc concepts thoroughly: “You don't want to try and push your way through this math, and maybe pass it, but not really get it.”

After his failing experience taking Calculus I, he decided to take Precalc the following semester to refresh his prior math competence/knowledge: “I'm now taking Precalc, just because I want. Also because I just want to make sure of my basic skills before I try advance math courses.” He was struggling in Precalc at the time of the interview due to the online course format. He is confident that his math competence/knowledge is good enough to complete the Precalc’s problems and assignments. The only problem was the online software that made students pace themselves, and he has gotten a little behind due to poor time management:
It's online [Precalc] so that's my biggest problem. It's all taught on ALEKS, so that's not really my style. So I'm a little bit behind in like the pace they want me to be at, but as for understanding the material I'm doing pretty well.

He spends between 1 and 1.5 hours per day working in his Precalc assignments and he usually spends a little extra time practicing math if a test was approaching. His ALEKS profile confirmed that he was spending almost six hours a week working on his Precalc assignments:

I will say an hour and 1.5 hours a day [working math], you know if there's a test definitely a little more so in a week um 7 to 9 maybe… I feel it's good enough but I could probably do some more, but I don't want to be burned out either.

He is planning on taking Calculus I during the summer; he believes that having more time to focus only in his math assignments will help him pass the course.

**Math SE:** This student reports a medium math SE (6.8 out of 10) after doing well in his math high school courses. He usually did better than his high school math classmates and that made him feel confident about his math competence/knowledge:

I don't know it’s just like, I did really well in my high school, so that definitively helped as a little kid, to have something where I was good at and some other kids might not have being as good in.

His math SE decreased after his failing experience taking Calculus I in college, but he was still showing a lot of confidence on his math abilities in general and did not mention a lack of math competence/knowledge as a reason for his struggles in math courses: “I know math, I'm good at math, it’s just that math [Calculus I] was a little too much, or maybe the
teacher just wasn't the right fit.” He remains confident about his math abilities even though
he was struggling in Precalc at the time of the interview; he believes he is underperforming
due to other factors different from poor math competence/knowledge: “I probably should
be like, you know getting an A instead of being a few steps behind. I'm not concerned, but
I just feel that I should be a little further ahead.”

His confidence on completing Precalc and his overall math SE seem to be higher
after having some experience with college math courses. He is feeling great taking a low
level math course, considering it as a good opportunity to refresh his math
competence/knowledge and adjust to the teaching style of his college math instructors:
“Yeah definitively it [my math SE] is better at Precalc. But it’s also just refreshing.” He
was confident about his ability to pass Calculus I during the summer due to the extra time
available to focus only on his math assignments:

I think Calculus I… I’ll be taking it during the summer, so I can focus all my time
on that. So I feel pretty good about passing that, especially having my... I already
kind of know what to expect now 'cause I did take half a year of Calculus I so that
definitely helps.

This student has some reservations about his performance in more advanced math
courses like Calculus II. He has being told by his friends that more advanced math courses
are very challenging, and even when he thinks that he is ready to take Calculus I and pass
it, he hesitates about his abilities to pass Calculus II: “But I've heard that Calculus II is
pretty hard, so I'm not sure what to think about that. So like I've just heard for some people
that Calculus II is one of the hardest math courses.” Although he has doubts about his
abilities to pass advanced math courses, he is confident that his math competence/knowledge could be good enough to complete these courses if he works hard and gets some help like he did before.

**Math competence/knowledge:** He scored high enough in his CMPT to start in Calculus I, but he performed poorly and withdrew after scoring a 40 in his first test. He took Precal the following semester where he performed better completing the 67% of the web assignments successfully; he performed well in the basic section where he scored a 77% (see Table C.6), and showed enough competence/knowledge in the advanced section material to pass the course. He was not prepared to take a college-level math course his freshmen year, and he reports struggling trying to understand the material and keeping up with the pace in his Calculus I course:

I guess Precalc is definitely the best fit, mostly because in Calculus I—I didn't know what was going on, 'cause the Calculus concepts thing [his Calculus course in high school] didn't help at all. Especially like, you know when I got there they [the instructors] were talking about the idea... just solving problems and I was like, ‘I don't even know what they are doing right now.’ I was prepare for Precalc, definitely nor for Calculus I. This Precalc is a good representation [of his math competence/knowledge] and Calculus I was a little to high for me.

He usually needs some extra time to really understand new math topics: “For math, I like to take my time, even if it's something easy. I just wanna make sure I know it 'cuase, you know if you kind of get it or like don't know it, I can have problems down the road.”
He is likely to ask a instructor or some kind of authority for help when he struggles to solve a math problem and the feeling of struggling working on math could frustrated him:

It just frustrates me 'cause I feel that it should be like this, and it's not. So it's like, I don't know… if I can't find and error in my board, that just really kind of confuses me. So I definitely try to seek help for, like ask someone, is this what you got? Or ask the teacher like, what's going on here? Just 'cause I wanna know if it's right or not.

Table C.6. Precalc Spring 2015 student performance in all ALEKS topic categories.

<table>
<thead>
<tr>
<th></th>
<th>Basic</th>
<th>Intermediate</th>
<th>Advanced</th>
<th>Total</th>
<th>Hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Algebra &amp; geometry Functions &amp; graphs Polynomial &amp; rational functions Exponential &amp; logarithmic functions Trigonometry Systems of linear equations &amp; matrices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2015</td>
<td>77%</td>
<td>63%</td>
<td>61%</td>
<td>67%</td>
<td>97</td>
</tr>
</tbody>
</table>

Academic behavior: This student was very confident about his math abilities before getting to college. Despite experiencing some struggles getting adapted to his college instructors’ teaching style and college math courses’ pace and difficulty, he remained confident that his math competence/knowledge was good enough to perform well in his college math courses. In high school, he had a good balance between his math SE and his math competence/knowledge, supporting his medium math SE with good performance in his math high school courses and scoring high enough in his CMPT to start in a Calculus course. He blames different factors other than lack of math competence/knowledge for his struggles in college math courses, thinking that he only needs to get used to working and learning math in his new college context to perform better and complete his college math courses: “That's [struggling in Precalc] mostly because of the time management, the fact
that it is online. The material itself I get it.” The Precalc online format affected his performance in this course, but he is still confident that he could pass it.

He enjoys working on math, even when he considers math a challenging activity:

> When you work a math problem and you get it right, like you know maybe you got frustrated while you work through it, but when you get it right, you get that sense like I did it. So I definitely enjoy that.

He is confident and motivated to face the challenges involved in learning math, and he is not intimidated by the difficulties that he may encounter in more advanced math courses like Calculus II: “I guess my strength is that I like math and I like the challenge. You know, I'm not going to be intimidated by it.” Although he likes math and he feels confident about his math competence/knowledge, his confidence in his math abilities were affected by the course’s context and class environment. He feels more confident about successfully completing his college math course when he feels supported by a instructor that cares about its students:

> When I get helped, it just helps me to remember more, 'cause when you go to ask someone you kind of recall the conversation. I do office hours definitely with the teacher, but if it is a minor homework problem. I go with my friends, or my roommate, or anyone that I know they are good at math, or they are in a higher level of math than I am. So you know they will know the problem or the topic I'm working on and they can help me.
His confidence in his math abilities makes him believe that he can get math faster that some of his classmates, but he prefers to take enough time for him to feel confident that he really understand new topics: “Even if I outpaced my peers, I still like, just slow down and, just really make sure that I have a good concept of what was learned.” Although he is confident that his math competence/knowledge will help him complete all his college math courses, he is aware that he needs to focus on his math course and study hard to be able to understand advanced math topics:

I'm kind of an unfocused person sometimes, so I have to make sure I study for the math 'cause sometimes I might forget it you know. I need to make sure I prioritize math to be like either at the top of, or close to the top of it.

**Math and engineering relationship:** He shows a broad understanding of how engineering problems can be solve using math tools and applications: “In high school I took like and intro to engineering and that was like a good introduction.” He is aware of the relationship of math with engineering problems, and he is using math to solve problems in his college courses: “Clemson has been the more like focused on engineering problems. In general I guess you need to be good at math and be able to be like a good outside the box thinker, you know like to be able to tackle problems.”
Long Calc Fall 2015 Student

Student description: This is a white female student with a math SE of 7 (out of 10). She got interested in chemical engineering after being involved in a research project where she had access to chemistry labs:

I got a research project at my high school, and a lot of the professors that I talked with... they recommended me to do chemical engineering because it was more what I was doing in the lab setting, so I decided to do chemical engineering. I really enjoy like drug discovery and production and so I want to go into that.

She likes math courses in general, and she seems to enjoy the challenge involved in learning new math topics: “I've always like math, but I've always had to work hard to do well so, it is a little more difficult for me, but I enjoy it.” She wants to continue learning advanced math topics and being involved in challenging math activities even after experiencing some struggles in her prior math courses: “I've always had a relatively good work ethic, so it takes a lot to discourage me to stop trying.”

Although she considers math a challenging activity, she does not report feelings of stress performing math activities; but failing to solve a math problem correctly could make her feel frustrated, especially if she tries to solve that problem more than once and she still having a wrong answer:

I'm relatively okay [working math] until I get a problem wrong, and then when I reworked it the first time and it's wrong in a different way, then I get like really frustrated because I tried it in two different ways and it didn't work.
She is likely to experience test anxiety due to the limited time provided in regular tests. Lacking enough time to double check her work usually causes her to make little mistakes like missing the correct notation in a math equation. She usually finishes her math test on time, but she prefers to have some extra time to make sure that her math problems are correct:

I always do worst on test than I do on homework, even though it is the same kind of problems. I think just because test anxiety and stuff. Which seems to be a little bit worst in math.

**High school experiences:** Her math high school preparation include college-level math courses like Calculus and some basic courses like Honors Algebra, Precalc, and Geometry. She struggled with Trigonometry and Calculus courses which were the most advanced topics that she learned in her high school: “The trig section was my hardest section because it was a lot of memorization and that was difficult.” The struggles that she experienced learning advanced math topics in high school made her believe that she would need to make an extra effort and work hard to understand difficult math topics: “Well at high school I struggled a lot more and so then, I felt like I was in the... I guess like in the group of people that really struggle and have to work really hard to understand math.”

Her high school was offering only Honors and AP courses and she tried to take an AP Calculus course at her senior year, but she was rejected because she did not have enough background knowledge for that course:

For my high school the lowest level that they offered was honors, so all my courses were honors or AP. I was in honors Calculus in high school, I was put there because
I was like rejected by the teacher to be put into any AP Calculus course, so it was kind of like… it downshoot me.

She thinks that she could have pass the AP Calculus course in her senior year, and being rejected from that course made her feel less confident about her math competence/knowledge.

**College math experiences:** This student scored high enough in her CMPT to start in Calculus I as her first college math course, but she decided to take Long Calc instead of Calculus I trying to refresh her math competence/knowledge and avoid difficulties on more advanced math courses like Calculus II. Her good basic math preparation helped her to perform great in her first college math course, making her believe that her Long Calc course was easier than her high school math courses; but she is aware that more complex math courses would come in her engineering curricula:

Long Calc and Long Calc II is like the slowdown of math and it's a little easier than my high school math courses. So it's nice but, I think once I'm in like Calculus II and the higher level math it will be... I've heard from people that are in it [Calculus II] now that it's very challenging, but rewarding if you do well.

Having a review of the math topics that she learned in her high school as her first math college course was useful to boost her motivation and confidence in her math abilities to complete all the math courses required by her major:

At the beginning of the year we did like a very basic review of algebra, and that kind of put me in the mindset of ‘oh, I can definitely do this, I've been doing this since fifth grade’ so that was really nice to begin with.
Her biggest challenge in the Long Calc course was the correct use of the math notation and signs in her equations solving problems, which is common in students’ first college year:

I think keeping my work straight with the right notation have been the most challenging part so far. That's where most of my points are taken off, from putting the wrong thing or forgetting an equal sign that at the end changes the whole answer.

Using the correct math notation is an important part of math that is sometimes overlook by high school instructors, but it does not means lack of math preparation. She reports working hard to complete all her math assignments, spending about 45 to 90 minutes working on math activities every other day. She usually spends this time solving her math homework as practice to get a better understanding of new topics, and she normally ask for help if she has some doubts:

The homework problems are generally how I've been able to study for this particular math class, because there's a lot of extra study material that we can use so I've being practicing problems a lot and it really helps.

**Math SE:** This student reports a math SE of 7 (out of 10) in her interview responses which are higher than her survey responses (see Table C.7) where she reports an average of 5.8 (out of 10). The difference between her interview and survey responses is caused by her poor confidence in performing well in math courses, especially in advanced math courses like Calculus II (see Table C.7). She is confident about her math abilities to perform math in daily activities and solve math problems, reporting an 8 and a 7.8 (out of 10) respectively.
in her survey responses (see Table C.7); this level of confidence is more in line with her math SE reported in her interview, where she also mentions being hesitant about her abilities to complete advanced math courses obtaining a high grade: “It [math SE] would probably decrease if I were in a harder level math course.” Despite considering advanced math courses a great challenge and being hesitant about her abilities to perform well in courses like Calculus II, she is confident that her math abilities and strong work ethic will help her to complete these math courses: “I don't think I will get an A in Calculus II. I'll probably stay around like a middle to low B, just because everything I've heard about that class sounded very... like a lot of work.”

Table C.7: Long Calc Fall 2015 student math SE.

<table>
<thead>
<tr>
<th>Math SE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Interview</td>
<td>7</td>
</tr>
<tr>
<td>Survey</td>
<td></td>
</tr>
<tr>
<td>Math activities</td>
<td>8</td>
</tr>
<tr>
<td>Math courses</td>
<td>1.6</td>
</tr>
<tr>
<td>Math problems</td>
<td>7.8</td>
</tr>
<tr>
<td>Average</td>
<td>5.8</td>
</tr>
</tbody>
</table>

She is confident that her good basic math knowledge will help her learn new and complicated math topics if she works hard and spends extra time practicing: “I have a good understanding of math concepts and what I'm doing right now, but I still have to work pretty hard to understand new concepts and new things.” She is planning to take Calculus II during the summer after completing Long Calc II in the spring semester. Calculus II is offered online during the summer, and the possibility of having less social support and resources makes her feel less confident about her math abilities.
I'm a little bit concerned about that [taking Calculus II] because it would be online so there is less of the support system, but as far as it goes, I feel that I will be able to complete everything on time.

Her confidence in her math abilities seems to be higher when she is working on math problems that represent daily activities or real world applications. She states having some experience solving this type of word problems using math applications: “That I feel very confident, for me is a lot easier to solve problems that have like a meaning behind them.” Having experience solving different types of math problems in her high school helped her to get adapted to her college math courses; and that makes her feel more confident about her math preparation. She feels better prepared for the Long Calc course than her peers who have not taken Calculus before:

I came in thinking that I was ahead of everyone else in the class already and so, that already like put me in a good mindset for learning. I'll say about half the people on my class have taken a Calculus course before, and the other half haven't. So the ones that have taken it I feel like equal to them, but the other ones seem to be struggling a little bit more because they haven't had this information before.

Math competence/knowledge: She scored high enough in her CMPT to start in Calculus, but she decided to take a lower level math course because she was told by her friends that Calculus is a very challenging course and it is easy to get left behind. She reports performing really well in her Long Calc course at the time of the interview: “I have not struggled in that class [Long Calc], I think I have an A right now, if not an A maybe a high B but I feel pretty confident.” She finished her Long Calc course with an 85 (see Table
C.8) and she did not struggled in any particular part of the course. She is happy with her decision of taking Long Calc because that gave her enough time to review some topics in a slow pace, but she believes that she was ready for a more challenging course:

I think that if there were a level in between Long Calc and Calculus I, then that's where I should be. Because I feel like if I've gone straight into Calculus I, it would have been, not necessarily too difficult but I feel that I would've left behind at the beginning, and then become discourage in learning more because I was lost.

She was performing well in her Long Calc II course in the Spring 2016 semester, scoring 72 and 74 in her first two tests (see Table C.8).

This student developed a good problem solving schemata to solve her math problems during her high school experiences (Gick, 1986). She usually starts solving a math problem thinking ahead of the possible outcome, or doing an estimation of the problem’s solution before starting plugin-in numbers into the equations. This working forward problem solving strategy promotes learning of advanced math topics and suggests good math abilities and experience solving math problems (R. W. Lent et al., 1984):

With word problems it's easier to sort of make an estimate of the right range for the solution. Um, it's easier to sort of like visualize in my head what would be a more logical answer, than like taking the derivative of a function.

Table C.8. Long Calc Fall 2015 student performance in his college math courses.

<table>
<thead>
<tr>
<th>Term</th>
<th>Course</th>
<th>Course average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2015</td>
<td>Math 1040 (Long Calc)</td>
<td>85</td>
</tr>
<tr>
<td>Spring 2016</td>
<td>Math 1070 (Long Calc II)</td>
<td>73 (not final)</td>
</tr>
</tbody>
</table>

Academic behavior: This student thinks that math is really challenging and she needs to work hard in her math courses to be able to understand the material and perform well.
Working hard to understand math is not difficult for her because she enjoys the challenge involved in learning advanced math topics: “I need to work really hard at them [math courses] so they are more challenging than other courses, but I enjoy doing that.” She could have started in Calculus I as her first college math course, but she decided to take a lower level math course trying to avoid getting left behind and getting to the following math course with some deficiencies:

The CMPT that I took put me right on the cut of line for Calculus I, so I thought that since I have struggled some in high school I should probably take the lower level, and not get left behind an be complete lost in Calculus II. So I think I probably could have done Calculus I this semester, but I think I did the good choice.

She is confident that her math abilities would be good enough to pass the Calculus I, but she chose to be cautious and took some extra time to reaffirm her math competence/knowledge before taking the most challenging courses in the future.

She reports a medium math SE level but her performance and math preparation suggest that her math competence/knowledge was a little higher than her math SE. This gap between her high math competence/knowledge and slightly lower math SE may be the reason of her hesitation and caution selecting advanced math courses. Having the opportunity to refresh her high school math competence/knowledge helps her feel more confident about her math abilities. Although she is cautious about getting involved in challenging math activities, she is likely to work hard, ask for help, and keep trying to understand new math topics even after experiencing some struggles with topics like trigonometry:
I think it [struggling with math] is part of your learning process because that is how I've learned in the past math classes. I generally raise my hand and ask a question to the teacher, our class is small enough to people to do that.

She normally tries to solve her math problems by her own, using the book if she has some doubts; and if she is not able to solve a problem by her own, then she asks for help: “[When solving math homework] I look in the book first, and then if I cannot find it from there, then I have a friend who is in one of the higher level math classes, and I generally ask her if she can offer any advice in the problem.” She is likely to use all type of resources to solve her doubts, and she works hard to understand her math assignments. She normally asks her friends, the instructor, or looks the text book or online before giving up solving a math problem: “I try very hard not to give up on a math problem because I get frustrated with it.”

Despite thinking that other students with a special talent to learn math could perform better that her without much effort, she considers herself as a hard worker and she works really hard to overcome any struggle learning math:

I've always had to work really hard understanding math concepts that a couple of my friends like, they just heard it once and then they are perfectly fine. So I think that there's a predisposition towards doing well at math, but anyone could work hard enough to get to that point.

**Math and engineering relationship:** She considers math an important skill for engineering, but she struggles to give an example of a math application that could help her to solve engineering problems: “[To become an engineer] I’ll need a lot of math in their engineering
version.” She did not take any engineering course before college, and her experience solving engineering problems was mostly doing unit conversions. Her basic math abilities have been enough to solve all the engineering problems that she has faced so far: “So far at this level of engineering classes I've been able to solve everything with what at know about math.” Having a good basic math competence/knowledge to deal with this engineering problems makes her feel confident about his abilities to solve more difficult engineering problems using math as a tool in the future.
Student description: This student is an African American male with a medium overall math SE of 6.5 (out of 10). He showed interest in general engineering since high school due to his abilities for fixing things, and he decided to pursue an electrical engineering major after taking a course that introduced him to this topic in his high school:

As a kid I had a knack for fixing things. I fixed my first Playstation, I didn't know how to do it so I just figured it out just by myself tinkering around, and I started doing that, fixing bikes and other stuff.

He showed motivation to pursue an engineering major after his residential teacher advised him to try electrical engineering due to the possible benefits that this major could offer him later, like job opportunities.

He does not feel stressed or anxious working on math activities, and he considers math courses as something that he can do easily: “I don't really find math classes hard at all.” He likes solving math problems, especially if he can apply his math competence/knowledge to solve real life problems. Although he enjoys working on math activities, he usually struggles on his math tests. He was likely to experience stress and anxious feelings when he was evaluated, and this test anxiety was an issue for all of his classes, not only in math:

I found them [math] essential. I do like doing math and solve... problem solving and applications and everything. Um, of course when it comes to tests, I'm not the best. It raises my... I get... I stressed out.
He considers that having good math competence/knowledge is important to be able to succeed in his engineering major, and he thinks that everybody could be good at math if they practice how to understand patterns: “I’ll say, um, anybody could be good at math. Math is just learning patterns, and learning, and memorizing how the patterns could be solved.” He thinks that solving math problems is a structured process, where you need to follow a number of specific steps to be able to successfully solve a math problem.

**High school experiences:** He took a lot of math courses in his high school, including a partial-year attempt at a Calculus course in his senior year: “I took uhhh... Precalc. I took Geometry, and Algebra I and II. And I took Precalc during senior year. I did mostly B’s in all my math classes.” He took Calculus during his senior year trying to develop a good understanding of advanced math concepts before getting to college, but the course’s level was difficult for him and he could not kept the pace. He dropped his Calculus course and he decided to take a lower lever math course instead: “In senior year I was trying to get out with a grasp of the concepts I was taking, and that was a little difficult in my Calculus I, so I just stopped and I just used the slide.”

**College math experiences:** This student took Long Calc the semester before the interview and failed it. He decided to take Long Calc the following semester after her failing experience and he was doing better at the time of the interview:

I took the same class [Long Calc] last semester and I pass with a D... well I didn't pass... I got a D. And taking it this time, I see like a lot of what I missed is obvious, so the subjects make sense, I understand how to solve the problems better, how to solve them faster, how to solve them correctly.
He is feeling more prepared to perform better his second time taking Long Calc, realizing that he was not ready to take a college math course the first time he took Long Calc: “I thought that taking a college math course would be different from high school, I just didn't know how . . . but I wasn't prepare [for it].” Although he is performing well in his second attempt at Long Calc, he realizes that college math courses are different from what he experienced in high school. His experience in college math courses taught him that math competence/knowledge is cumulative and if you don’t learn how to use all the material to solve complex math problems, then you may struggle understanding the advanced math topics later:

In college it’s not the same, each subject blends into the next section until the final, and is like remembering all the little stuff. And if you didn't have a good understanding of this blending, you can't remember how to do it . . . It’s definitely more difficult, maybe just because I haven't adjust to it yet.

He spends approximately three hours per week working on his math assignments outside his class time. He usually uses this time to solve his online assignments, and to practice. He normally works on his math activities during class, and he is likely to stop working on his math assignments if he struggles working on them at home: “I just do the webassign or my homework, and for written homework I usually save like... I'll do it while in class or I'll do it at the beginning of next class.” He is comfortable with the Long Calc’s difficulty level, thinking that he is ready to learn the math topics after having a prior experience where he learned how to manage the class pace and the college instructors’ teaching style:
Yeah, I'm definitely in the right place. It’s like, taking it the second time slows it down for me, and now I know. I remember last time and I'm finally getting it this time, is like a little slower, and it seems slower to me, so it's like easier to do the assignments.

Math SE: The math SE that this student reports in the interview (6.5 out of 10) is lower than his math SE in his survey responses (see Table C.9), where he reports an average of 7.9 (out of 10). His survey responses show that he is confident about performing math in his daily activities with an 8.4 (out of 10), and solving math problems with an 8.8 (out of 10), but his level of confidence performing well in several math courses is lower than that, reporting a 6.9 (out of 10), which is closer to the math SE that he reports in the interview (see Table C.9). This student is confident performing math activities and solving math problems in class, where he has access to different resources to help him solve his doubts in case he struggles: “I think I feel really confident [solving difficult math problems], since I can refer back to simple stuff that I might forgotten.” The reason why this student’s overall math SE is low is that he does not feel confident enough to perform well in math tests, where he does not have access to his notes and he cannot ask others for help:

Um, in class I'll say about an 8 [math SE] and in a test I'll say about a 5 [math SE]. In class I just look to my notes and I understand it, and during the test you know they don't look the same to me, or I don't see them as the same, and I just get confused. I kind of like… I just answer what I really know how to answer.
Table C.9: Long Calc Spring 2016 student (1 of 3) math SE.

<table>
<thead>
<tr>
<th></th>
<th>Math SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interview</td>
<td>6.5</td>
</tr>
<tr>
<td>Survey</td>
<td></td>
</tr>
<tr>
<td>Math activities</td>
<td>8.4</td>
</tr>
<tr>
<td>Math courses</td>
<td>6.9</td>
</tr>
<tr>
<td>Math problems</td>
<td>8.8</td>
</tr>
<tr>
<td>Average</td>
<td>7.9</td>
</tr>
</tbody>
</table>

He is likely to experience test anxiety for most of his courses, not only math, which affects his confidence getting good grades in math courses.

He is confident that his math abilities will help him to understand the Long Calc material, especially after taking the course the semester before. He feels more confident about his math competence/knowledge his second time taking Long Calc, thinking that he is better prepared after using his first Long Calc experience as an opportunity to get used to college math courses:

I just had my last test, and when I was doing it, I understood how to do it after seeing the same problems in class and just switching the application around. So I feel more confident about doing it this semester.

Although his math SE is still in a medium level during his second attempt taking Long Calc, his math SE improved compared to the first time that he took the course: “My level of confidence last semester was like a 2 [out of 10], and this semester I feel more confident.”

His confidence in his math abilities and perception about math courses did not change when he went to college, as he reports that his math SE in high school was about the same. He mentions feeling underprepared to take a college-level math course when he took his first math course at college, but his math SE is a little bit higher at the time of the
interview because he was feeling more familiar with the topics and the way that tests were
designed. This student’s confidence in solving math problems seems to be related to the
possibility of looking his notes, having access to similar examples to guide him, and having
some people to help him if he struggles. His confidence solving math problems decreases
when he does not have access to these types of resources, and he doubts his abilities to
perform well in advanced math courses. He is confident about completing all the math
courses required for his major, but he does not think that he will be able to finish them with
good grades, or without experiencing some setbacks.

Math competence/knowledge: He reports having good grades in his high school math
courses (mostly B’s) and he scored a good grade in his CMPT (76), suggesting that he
came to college with a good basic math preparation. Despite his apparently good basic
math preparation, this student performed poorly the first time that he took Long Calc,
scoring a low grade on each of his tests and earning a final grade of 29 (see Table C.10).
He is doing better in his second attempt taking Long Calc. His performance in Long Calc
was barely passing at the time of the interview, but he is feeling better about his
competence/knowledge and he is understanding the course topics better. He scored a 77 on
his first test and a 54 on his second one, and he is confident about passing the course with
these grades. He considers his performance in the Long Calc course to be a good
representation of his real math competence/knowledge, which should be enough to
complete the course, but not enough to get better grades: “I just took the first test for math
and I got a B, and that represent well my math abilities.”
He normally struggles solving math problems when he cannot use his notes, or others’ help, or he does not have a previous example to help him, which makes him feel confused and less confident about his math competence/knowledge. He is likely to use a work backwards problem-solving strategy (Gick, 1986), where he tries to use only the numbers provided by the surface data of the problem and follow the steps used by the instructor to solve practice problems before:

I try to look for key words like during the class, and remember to pair those words with the numbers used in the... I might not look to the whole question, I just know that I have to look if I’ve seen a question like this before.

This problem solving strategy suggests that this student does not have much experience solving college-level math (Larkin et al., 1980).

Table C.10. Long Calc Spring 2016 student (1 of 3) performance in his college math courses.

<table>
<thead>
<tr>
<th>Term</th>
<th>Course</th>
<th>Course average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2015</td>
<td>Math 1040 (Long Calc)</td>
<td>29</td>
</tr>
<tr>
<td>Spring 2016</td>
<td>Math 1040 (Long Calc)</td>
<td>66 (not final)</td>
</tr>
</tbody>
</table>

**Academic behavior:** This student likes math courses and he finds value in learning different ways to use math to solve all kind of problems: “I do like, ah like learn how to solve certain problems, and why you solve them in certain way, and how they change depending on how you solve them, so I really enjoy taking math.” His medium math SE is a good representation of his basic math competence/knowledge. His medium math SE makes him feel confident that he can complete all his math college courses if he works hard. He spends extra time working to improve his math competence/knowledge in his second attempt taking Long Calc; he works by himself and also tries to get help to understand the material:
Just practicing, not only in class but out of class; doing the homework like web assignments, they are really helpful. But writing homework does my better, um, 'cause then I have to look into the book for an answer, or comparing to like how other people solve it.

Failing his first attempt at Long Calc helped this student have a better estimation of his math SE compared to his math competence/knowledge. His math SE was really low the first time that he took Long Calc, but that was because he did not feel ready to take a college-level math courses. The differences between high school and college math courses made him struggle and he was feeling lost during the course, and he did not put enough effort into it. He took this failing experience as a wake-up call that helped him realized that he need to work harder to be able to complete his college math courses. Despite failing his first Long Calc attempt, he remains motivated to work harder and practice to get better at math: “I'll say my strengths would be probably that I see me in class practicing and being there, learning how to apply it [math] in different situations.” Having a good balance between a fair math competence/knowledge and a medium math SE helps him to keep trying to improve his math abilities and to ask for help when he is struggling to understand a math topic:

I think I do need help. I try to mark the subjects that I haven't understand and then, maybe go back to see why I'm struggling with that subject, and try to go online, and look for it, or maybe ask other people that have solved the problem.
He is barely confident about completing all the math courses required to become an engineer, and was likely to get discouraged if he struggled to understand complex math topics in more advanced math courses in the future.

If I work my best and then fail... I would feel like I did everything, and I used all my applications, and all my ideas, and everything that I knew, and I still didn't get it right. And I would figure maybe what's the point to taking it.

He states that he usually stops working in his math assignments when he struggles finding a problem’s solution. He does not try to solve math problems more than once, especially if he does not have something similar to be used as an example to help him solve the problem:

[If I’m struggling] I would look back at the equation and see how I worked it out, and if I don’t see something wrong in how I worked it out, then I kind of just... I just stop if I don't know where to go from there.

Failing Long Calc and taking it the following semester helped him feel more prepared to pass it the second time, but failing a math course in the future could make him doubt about his math abilities to complete the course if he tries again:

I don't feel really confident anymore. If I can’t solve it [math problem] the first time, I start losing confidence in how easy I can solve it 'cause now I think it is a hard subject in the back of my mind, and I’m not going to get this, so I kind of don't want to do it.

**Math and engineering relationship:** He realized that math has an important role in engineering once his college courses started to use math applications to solve engineering problems: “Math--I've started to see that math is very important [in engineering], it have
appeared in a lot of my classes lately.” He does not mention any relation between his math abilities and his decision to pursue an engineering major, but he feels that his math abilities are good enough to solve the engineering problems that he has faced in college courses:

Like break even analysis, learning slope, slope was important in engineering 1060, um, limits, limits are very important [solving engineering problems] too. Like a basic math, um, like learn how to convert.
Precalc 2016 Student

Student description: He is a white male engineering student with a high overall math SE of 9 (out of 10). He got interested in engineering because he always want to know more about how cars and other things work. He would like to work in the car industry finishing his engineering degree, and he also thinks that earning an engineering degree will help him get a good job: “I've always kind of been interested about like how things work, and I've always been kind of good at math, so I guess I just picked the one the best fit my interest.” He is very confident in his math abilities, which helped him realize that engineering could be a good major for him.

He believes that some people could have better abilities to learn math, but anyone that really want to learn math could develop a good math competence/knowledge if they work hard and ask others for help: “I think some people are born better at math than others. But if you are really not that good at math, but you wanna learn math and you wanna pursue something that involves math, I guess you can go to tutoring and you can use all the resources and kind of... kind of have things to help you I guess.” He used to think that he was really good at math due to his successful experiences taking math courses in high school, but his confidence in his math abilities decreased when he got to college and math courses became more challenging: “I knew I've always been good at math from like elementary school up to high school, but now it is getting in more depth and in the hardest stuff I kind of... kind of don't feel like I’m that good anymore.”

High school experiences: He took a lot of math courses in high school. He decided to take college-level math courses since his junior year, showing to be interested in the
development of his math competence/knowledge: “I took Algebra II, Geometry, um, Trigonometry, Advance functions, and modeling, and Calculus AB. I actually did Precalculus too.” Hi did very well in his math high school courses, scoring a high grade in all of them with the exception of AB Calculus. He reports experiencing some struggles with some topics in his AB Calculus course, but he still got a low B. Despite his struggles taking AB Calculus in his junior year, he took an additional math course his senior year trying to accomplish a thorough math preparation: “I got all As in all except Calculus, I think I got a low B in Calculus. I took Calculus in my junior and so I took Advance functions and modeling my senior year.” He had only good experiences taking math courses in high school, and he did not mentioned any complication learning and performing math, even when he took some college-level math courses. These good experiences learning math made this student developed a very good confidence in his math abilities: “in high school math was like a breeze to me, I was like 10 out of 10 in all of my classes.”

**College math experiences:** He took Long Calc as his first college math course and he failed it. He states that the reason for failing the Long Calc course was that the difficulty level and math problems are harder in college courses, and he found Calculus to be a very complicated and challenging topic. He has considered Calculus a tough topic since high school, but he realizes that college Calculus would be tougher than he was thought before coming to college: “I guess Calculus is just hard for me ’cause Long Calc was pretty hard, and I guess Calculus II will be even harder. So I guess it’s just like, I guess everything was easy but Calculus is where I'm struggling. Like, I was good at algebra and everything.” Despite his good performance in math courses in high school, he reports experiencing a lot
of struggles in his first college math course. These struggles learning hard topics like Calculus made him realized that he would need to work harder and look for extra help and supports to be able to understand his college math material: “I used to be very good, but now they [math courses] are getting harder and is kind of... kind of more work for me, like I have to go to tutoring, and SI, and everything, is like I kind of struggle sometimes.”

After failing his first college math course he decided to take a lower level math course, and he took Precalc the following semester. During the interview, he reports working 4 hours per week on his Precalc web assignments, but he actually spends more time working on his math assignments according to his ALEKS profile: “I probably spend like 4 hours outside of classwork on it.” He reports being in a good pace to finish his webassignments at the moment of the interview, and his ALEKS profile showed that he spent 89 hours working on math problems online. The slower pace and easier material of Precalc compare to his experiences taking Lonc Calc was a good fit for him. He mentioned that he was able to understand the material better with the Precalc software’s help and he was performing well at the moment of the interview: “I like the way it [ALEKS] is set up, 'cause it will tell you when is wrong and it will give you like problems exactly like the ones you did for practice.”

Math SE: This student reports high math SE in both, his interview and survey responses. He reports a math SE of 9 (out of 10) during the interview, and that math SE was the very similar to the average of his survey responses where he reports a 9.3 (out of 10) (see Table C.11). He reports a higher math SE performing math in his daily activities (9.4 out of 10) and solving math problems (9.5 out of 10) than performing well in different math courses
(8.9 out of 10). He reports the main reason for his slightly lower confidence performing well in his math courses was his lack of confidence to perform well in Calculus courses, especially in Calculus II.

Table C.11: Precalc Spring 2016 student math SE.

<table>
<thead>
<tr>
<th>Math SE</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Interview</td>
<td>9</td>
</tr>
<tr>
<td>Survey</td>
<td></td>
</tr>
<tr>
<td>Math activities</td>
<td>9.4</td>
</tr>
<tr>
<td>Math courses</td>
<td>8.9</td>
</tr>
<tr>
<td>Math problems</td>
<td>9.5</td>
</tr>
<tr>
<td>Average</td>
<td>9.3</td>
</tr>
</tbody>
</table>

His level of confidence in his math abilities are different depending on the course difficulty level. Advanced math courses like Calculus make him feel less confident about his math abilities, and he considers college courses harder than his high school courses in general: “In Precalc I'm actually pretty confident if I have the resources, 'cause is just basic Calculus and Precalculs. But if it was any harder I would be probably a lot less confident.” Although he took some college-level math courses in his high school and he did really well in most of his math high school courses, his confidence in his math abilities decreased when he got to college. He states feeling underprepared to take a college Calculus course in his first year at college, and he is using his experience in Precalc to practice and improve his math competence/knowledge so that he can be ready for the challenge: “I know like Algebra II and Precalculus gave good background for a lot of foundations to start, but I feel like I should have taken Calculus in high school more seriously, because I feel like it could have prepared me better. But I didn't take it as seriously as I could have so it prepare me some, but not well enough as it could have prepare me.” He is more likely to be confident that he can perform math activities when he is not facing Calculus problems, and
his confidence about solving all kind of Precalc problems was really high at the moment of the interview: “I'm pretty confident in this one 'cause is Precalculus. I took Long Calc last semester but that was a pass/fail class and I didn’t pass.”

Despite his struggles taking college-level Calculus courses, this student is confident that he can finish all the math courses required by his engineering major. He mentions that he is planning to take both Calculus I and Calculus II during the summer, and he does not doubt his math abilities to complete both courses. He mentions that these advanced math courses are going to be really challenging, but he is confident enough that his basic math competence/knowledge will be enough to complete them if he works hard and gets some help: “I'm pretty confident, 'cause they say Calculus II is the hardest… so I'm actually taking Precalculus, and then over the summer I want to take Calculus I, and in the second term I guess I want to take Calculus II. So I guess that means first semester next year I'll take Calc III.” Hi is equally confident in his abilities solving all kind of math problems like graphics, word problems, or reworking a problem to fix mistakes; and he does not report struggling with any specific math topic other than Calculus: “Most of the time I feel good [reworking a wrong problem], because most of the time is just that I plugged in the number wrong, or I divided it instead of multiply it, or something silly like that, so I'm pretty confidence in that.”

Math competence/knowledge: This student reports having good grades in all his math courses in high school, scoring A’s in all his math courses with only one B in his AB Calculus course. His great performance in high school can be an indication of a good math preparation, especially because he took a couple of college-level math courses in his junior
and senior year. Despite his good record and performance in high school, he performed poorly in his first college math course, and he failed it. He was taking Precalc at the time of the interview, and he was performing really well. According to this student’s ALEKS profile, he finished Precalc, completing 83% of the webassignments, scoring a 77% on the advanced section and 92% in the basic section (see Table C.12): “Actually I'm doing a lot better in this class. It's online and Long Calc was in person, but I feel that I'm doing better 'cause I understand the material better in Precalc.” He states feeling more comfortable with the Precalc topics and course pace, and he did not struggle understanding the material in this course.

He demonstrates good basic math competence/knowledge and he is able to solve Precalculus math problems without much effort, but he reportes spending the necessary time checking his class notes and textbook when he is practicing to master new math topics: “[If a problem’s solution is wrong] I'll probably take the online textbook to make sure that I'm doing the right way, or I'll go back and check for careless errors 'cause I make those a lot.” He normally uses simple strategies based on the problems’ surface information to solve math problems, suggesting that he does not have much experience solving problems using math applications (Larkin et al., 1980): “I read it, and like asses the equations, and read the problem, and understand what is going on, and then if there are formulas to use, I find the formulas and plug in all the numbers I guess.” He reports using logical reasoning to evaluate his math problems’ answer, but he just estimates a broad approximation of the possible size of the final answer, and then he compares his final answer with that estimation. He is also likely to compare his final answer with a friend or other person work,
to determine if his answer makes sense or it is way off range: “So I guess if it's too far off, I ask a friend or something, and if it's off from that, then I redo the problem.”

Table C.12: Precalc Spring 2016 student performance in all ALEKS topic categories.

<table>
<thead>
<tr>
<th></th>
<th>Basic</th>
<th>Intermediate</th>
<th>Advanced</th>
<th>Total</th>
<th>Hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Algebra &amp; geometry</td>
<td>Functions &amp; graphs</td>
<td>Polynomial &amp; rational functions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Exponential &amp; logarithmic functions</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Trigonometry</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Systems of linear equations &amp; matrices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2016</td>
<td>92%</td>
<td>80%</td>
<td>77%</td>
<td>83%</td>
<td>89</td>
</tr>
</tbody>
</table>

Academic behavior: This student took his failing experience in his first college math course as a reality check, using this experience to realize that he did not put enough effort and he would need to work harder to be able to perform better in college math courses: “I didn't pass the first part of the Long Calc. It was kind of... kind of a reality check, 'cause I guess I could have studied more, went to tutoring more, and stuff to make my grade better in that class.” He is more likely to look for help to understand his math assignment after failing his Long Cal course. He states that he is working harder in his Precalc course, and he is taking advantage of all the special resources offered by the university to help him to learn the material: “I know now that I have resources like tutoring and the SI, so I will use those as much as I can to get the highest grade that I can.” He was overconfident about his math abilities when he got to college, and failing his Long Calc course helped him understand that his basic math competence/knowledge is not good enough to complete a college math course without effort and hard work.

He completely changed his approach to math courses when he was taking Precalc, spending a good amount of time practicing and solving his math assignments. He states that he needs to study and practice enough before a test or he will feel anxious that he may
forget something important; he feels more confident when he knows that he studied enough to understand the material, even when he has good basic math competence/knowledge for this course: “If I feel like I'm prepared [for a test] I'll do great, but if I feel like I'm not prepared, and I know that I didn't study as much as I should have, it’s a little hard for me, 'cause I get a little nervous and I kind of forget stuff sometimes.” He reportes working on his math assignments diligently; he tries to solve the problems that he was not able to finish in class during his free time, and he spends extra time studying when a test was approaching: “I go through my notes like… When I get back to my door room, I like read my notes and finish up anything that I left blank, and then about a week before the test I actually start like studying harder.”

He shows great confidence in his math abilities to complete all the math courses required by his engineering degree. Even after failing his first college math course, he remains confident that he could complete advanced math courses in the future if he continues working hard and seeking help to improve his math competence/knowledge. “I will [finish engineering] even if that take an extra semester, or a year of college. I think I would because this is for sure what I want to do.” Despite considering math topics very difficult, his high math SE helps him to keep trying to get a better math competence/knowledge, making an extra effort to spend more time practicing math, and taking advantage of all the resources available to support him in case that he struggles to understand the course material: “Sometimes I do [get stressed working math] if I don't understand it, 'cause I like to feel like I understand everything in a math class but lot of times I have difficulties.” He is likely to ask for help if he faces difficulties to understand
some topic in his math courses, stating that getting help is an important part of his new approach to be able to complete college math courses: “Usually the first person I go to is like a friend or a classmate, and then I probably go to office hours with my professor, and then I live in dorms so we have tutoring every night so I can go to tutoring.”

Math and engineering relationship: This student considers the development of math skills an important part of getting an engineering degree, but he has a poor idea of how math could be apply to help engineers to solve problems. He thinks that math could help engineers improve their problem solving skills, by helping them develop their critical thinking and abilities to think in different solutions for a problem: “Um, definitely math skills, and good problems solving skills. [to become an engineer] I guess you gotta know how to do math to like use all the formulas and everything and apply those to solve the problem.” He is very confident that his math abilities will be good enough to help him solve simple engineering problems, but he mentions that he could struggle understanding how to apply math to solve more complex engineering problems.
Student description: This is a white male engineering student with an overall math SE of 6.9 (out of 10). He was home schooled until high school, and the first math course that he took in a public school context was Algebra I. He became interested in engineering at a very young age. His father’s work as an inventor and entrepreneur had a big influence on his decision to enroll in high school engineering courses:

My dad is an entrepreneur, and inventor, um, and small business auto employed, etcetera. And he works with several engineers and scientists and such, and that helped inspiring me a lot.

His attraction to computer engineering was in designing and building robots, but he choose computer engineering in an attempt to avoid the hardest math courses:

I'm most interested in computer and mechatronics, or robotics engineering 'cause my passion is robotics. I choose computer over electrical or mechanical because um I knew that mechanical was so heavily math focus.

He thinks that anyone could be good at math if they work hard to understand it, but he believes that some people get math easier than others and that less talented people would need to make an extra effort to develop good math competence/knowledge: “I think math is... obviously some people are going to find it easier than others, but with enough effort I think that everyone can get at least to a pretty high math level.” He considers his math abilities to be above average compare to other freshmen students, but he acknowledges that his work ethic is not as good as it should be to learn advanced math topics in the college context:
I think that my ability to grasp math is above average in the total college population right, is average maybe a little bit above average in my math class, but my effort is fluctuating dramatically.

**High school experiences:** This student feels that his homeschool education prepared him well for his high school math courses. In fact, he believes he was better prepared than other students in areas like problem solving. He spent most of his math practice time working on word problems and applications, and having all the time that he needed to solve every problem helped him really understand how to use math to solve problems: “My homeschooling curriculum focused really heavily on word problems, there were always a couple of word problems.” His first high school math course was a low level, Algebra I course. He found the math topics and class pace to be a good fit for him, which helped him adjust to the change from homeschool to public high school classes. He did well in the Algebra I course and decided to take more math courses the following year to try to catch up with his classmates who came with math credits from middle school. He also took math courses during his junior and senior year, including a Calculus course as a senior:

I took Algebra II and Geometry simultaneously my sophomore year in an attempt to catch up to the other students. Then I took Trigonometry or Precalc in my junior year, and then Calculus CP on my senior year.

He did great in his first high school math courses making A’s and B’s:

I started with like a 97, a really high A in Algebra I, and it was kind of downhill from there. I made an A in Geometry, I made an A or B in Algebra II, um, I might have made an A in Trigonometry.
But he started to struggle when in higher level courses as he struggled to keep up with the faster pace. He was placed in a low level version of Precalc, and he thought this course was very easy for him and ultimately affected his interest and engagement in the class. He performed well in his Precalc course, but he did no learn the basic math skills necessary to move on to more difficult math topics in Calculus:

My Precalculus class had an amazing teacher, but I was in the dumb kids version of the class, so it was easy. It was so easy for me. I remember I would like do my history homework in that class and figure out the math on the test, and so I made an A. But I didn't make an A because I did learn much right, I didn't learn any trigonometry.

He struggled to understand the material and keep the pace in his high school Calculus course due to the lack of solid mathematics background. He feels that his previous course did not prepare him to learn advanced math topics:

I went into Calculus without being challenged properly, and then I did Calculus and I really struggled there, 'cause I didn't have the background. I wasn't updated with my algebra skills so I was just learning to... just how hard the algebra was.

College math experiences: He took Calculus I as his first college math course, but he did not feel prepared for the fast pace and advanced math topics in that class. He ultimately decided to drop down to a lower math level course:

I started in Calculus I because I had Calculus experience in high school, but my Calculus was rough and my math skills were not ready for that class. So I was working really hard, and a month into the semester I was just really stressed and I
went to my advisors, and they dropped me down to Long Calc which I felt much more comfortable with. He felt more capable dealing with the Long Calc class’s slower pace. His experience in his first college math course was challenging because he had to adapt to the testing time restrictions. “Just being able to do the whole time deal is, for me is... Even now after four years of it, the idea of taking a test in like 60 minutes or 40 minutes it’s...”

Although he reports feeling more comfortable with the Long Calc pace and material, he failed the course at the end of the semester. He states that the main reason for failing Long Calc was that he felt very relaxed after dropping down from Calculus I. He believed that his math competence/knowledge would be enough to pass the course without spending any extra time to practice solving problems faster:

It got so much easier when I dropped to Long Calc that I think that I got a little too comfortable. I wasn't putting in all the time, and I wasn't practicing enough. So like I said when I went into the test, even if I could do the problems, I went into all four tests being able to do the problems, but not being able to do them fast enough to finish the test on time.

He decide to take Long Calc again the following semester, and he performed better and now feels more confident about his ability to pass the course. He was spending two hours per week working on his math assignments outside of class time: “We don’t really have a lot of homework in my class like, if we get one, two, say two homework a week, that would take me an hour each, that’s six hours total.” He is confident that these two hours were enough to solve and understand the Long Calc homework.
Math SE: He has a medium math SE during his interview with a 6.9 (out of 10) but his math SE according to his survey responses is higher than that, reporting an average of 8.8 (out of 10) (see Table C.13). He is consistently confident in his math abilities in all his surveys responses, with math SE values for his confidence performing math in his daily activities, solving math problems, and performing well in different math courses ranging from 8.6 to 9 (out of 10) (see Table C.13). His lowest math SE in his survey responses is his level of confidence performing well in advanced math courses like Calculus I and II, reporting a level of confidence of 7, which is more aligned with his interview responses.

Table C.13: Long Calc Spring 2016 student (2 of 3) math SE.

<table>
<thead>
<tr>
<th>Math SE</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Interview</td>
<td>6.9</td>
</tr>
<tr>
<td>Survey</td>
<td></td>
</tr>
<tr>
<td>Math activities</td>
<td>9</td>
</tr>
<tr>
<td>Math courses</td>
<td>8.6</td>
</tr>
<tr>
<td>Math problems</td>
<td>8.9</td>
</tr>
<tr>
<td>Average</td>
<td>8.8</td>
</tr>
</tbody>
</table>

He is very confident that his math preparation would be good enough to complete his Long Calc course if he sets aside enough time to study and practice:

I'm confident in my ability to do the [Long Calc] material. I think if I put an appropriate amount of study time in and preparation time, I can be successful in the class, maybe B successful.

He is confident in his math competence/knowledge and believed that he would have been able to pass his Long Calc course the first time if he would have had more time to finish the tests: “If I would’ve had 50% more time during the tests, I would have passed all four of the tests, and I would have done a A’s or a B’s.” He thinks that college math courses are very challenging and performing well is hard for him: “I see A’s in math class at this point
as a little bit unattainable.” Even though he recognizes that college math courses would be very difficult for him, he shows great confidence in completing all the math courses required by his engineering major. He plans to take two Calculus math courses during the summer, and he feels confident that he could complete these two courses if he works hard and focuses all of his attention on the material:

I think I'm going to pass this math class and then, my plan is to take Long Calc II and Calculus II through the summer, so I can finish general engineering by the end of the academic year.

Despite showing great confidence in his abilities to complete his math college courses, he shows less confidence in his math abilities when asked about specific math tasks like solving math word problems or completing homework after being taught a new topic. This student’s math SE could be affected by the difficulty and context of the math activity he is trying to perform. His math SE decreased after he transitioned from high school to college math courses. He struggled to keep the pace in his first college Calculus course and this negatively affected his confidence in his math abilities. After changing to a lower level math course, his math SE increased until he started struggling to complete tests in the allotted time at which point his math SE decreased again:

When I was in Calculus I for the first month of school, I was like very low confidence. I though my best case scenario was like barely get a D average, and you know that's failing. And then I dropped down to Long Calc, and initially I felt confident although I lost confidence over the year 'cause it just never worked out.
Additional factors that may affect his level of confidence in his math abilities are the instructor’s teaching style and the class pace. He prefers to have an experienced instructor that cares about students’ learning, and can present math topics in an engaging way: “Having a professor that is engaging and that is willing to put extra time in and is confident on himself is nice.” The student is more comfortable with slow pace classes and tests designed to be taken in long periods of time: “The pacing is another major factor, because the tests are really fast paced and is all about speed, it’s not my kind of test.”

**Math competence/knowledge:** He reports having good grades in his high school math courses, and he scored high enough in his CMPT to start directly in Calculus I. This good performance in precollege math activities would suggest a good basic math competence/knowledge, but he struggled greatly in Calculus I and had to drop the course. He also struggled in his first Long Calc course (see Table C.14), but his final grade was a 64, which was almost a passing grade. He struggled to adapt to the college math courses context and class pace, so this performance in Long Calc could be interpreted as having a fairly basic math knowledge but poor experience with college courses. He was taking Long Cal for the second time at the time of the interview, and despite reporting doing better, his tests’ grades were very similar to his first attempt at Long Calc. He made a 68 on the first test and a 62 on the second one (see Table C.14).

He usually applies a problem solving strategy often used by more experienced students (Larkin et al., 1980). His problem solving strategy involved analyzing the problem and then trying to use his previous knowledge and experience to break the problem in different parts. After solving each part separately, he would combine them to come to an
overall problem solution: “I try to break it apart ahh... Really try to understand what's going on in a conceptual level right.” He feels prepared to solve problems applying his math competence/knowledge, and he is aware that most students struggle with this topic: “I've had a lot of success with that [math word problems], I know that I'm more comfortable than most students in word problems.”

Table C.14: Long Calc Spring 2016 student (2 of 3) performance in his college math courses.

<table>
<thead>
<tr>
<th>Term</th>
<th>Course</th>
<th>Course average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2015</td>
<td>Math 1040 (Long Calc)</td>
<td>64</td>
</tr>
<tr>
<td>Spring 2016</td>
<td>Math 1040 (Long Calc)</td>
<td>65 (not final)</td>
</tr>
</tbody>
</table>

Academic behavior: This student’s math SE was previously high, in fact, math was his favorite subject. This changed when he began struggling and experiencing setbacks in his advanced math courses due to his poor understanding of basic Precalc topics:

Math used to be my favorite subject, but ever since that sort of junior year at high school where I felt behind so dramatically in my ability to do it, I hated it! But I hated it because I was struggling with it, and I'm still working to get back up to speed.

He still enjoys solving math problems, but he needs to be sure he completely understand the math involved to avoid feeling stressed when working on a problem:

I don't even think that I hate math, 'cause I enjoy talking about mathematical concepts with professors. I just hate the struggle. I hate when you can't do it, and you sit there over ten online homework problems for hours and is like... if I could do this in 20 minutes, math would be my favorite subject.
Although he reports having a medium math SE in his second semester in college after failing his first college math course, this student is confident that he could apply his good basic math competence/knowledge to complete his college math courses: “It’s all either straight in the online, and there are resources right there in the website. So yeah, I’m pretty confident [passing Long Calc].” He was resilient through his past failures in math courses, and he is likely to keep working to improve his basic math competence/knowledge even if he continues facing some setbacks in his college math courses.

After initially struggling and failing his first college math course, this student showed good balance between his medium math SE and his good basic math competence/knowledge during the following semester. He spends more time working on his math assignments his second time taking Long Calc, and he is more confident in learning new topics, especially if he is able to ask questions and clarify doubts. Despite being confident about completing all the math courses required by his major, he anticipates that advanced math courses will be difficult for him: “Yeah I have a lot of friends that are a lot better at math than me currently, and they are working really hard on that class [Calculus II].” And he is prepared to take advanced math courses multiple times if necessary.

Although he needs a lot of practice to feel comfortable solving problems on a test, he does not show strong motivation to work by his own. He chooses to only complete homework assignments when they count for a large percentage of his final grade: “If is an online homework that really doesn’t matter in terms of your grade, I will honestly skip it.” His approach is different when he has structured support to help him practice: “Well I
would seek one-on-one assistance from the professor, and I would go to tutoring sessions that they have available. When I don’t know what is going on that’s what I do.” He is more likely to seek out help and spend extra time practicing math when he was helped by experienced people that really understand the material:

In Calculus I, they have this math tutoring they did like 3 to 6, and I love that because they have the same student teachers that were teaching it you know. The grad students take turns to be there.

He uses his homework assignments as his only practice time, and he does not report spending extra time practicing math. He feels confident enough to perform well on a tests after completing his homework assignments:

I don’t honestly do a lot of math studying, I never have. I’ve always felt that the homework is the studying. If you didn’t do the homework and understand it the whole time you are pretty screwed.

This student seems overconfident about his math competence/knowledge when he feels that he understands all the material. He typically stops practicing and becomes relaxed when he does not feel challenged by the math activity: “It [Long Calc] got so much easier and I just relaxed, and I didn't put in enough effort. I didn't pursue practice and it was the reason I failed it.” On the other hand, he became stressed when he struggled to solve math problems, and these struggles often negatively affected his level of confidence in his math abilities. These recent struggles associated with learning and applying math principles at a college level cause this student less likely to spend time practicing to get better at math. However, he is aware that he would need to put more effort and practice time into his
subsequent math courses or he will not be able to complete all the math courses required by his major: “I think that I can put a lot more effort in, and if I did I would do better. That’s probably the key concept.”

Math and engineering relationship: This student considers good math competence/knowledge to be an important component in pursuing an engineering major: “Um, well you have to be good at math [to become an engineer], good at analyzing the problem systems, that kind of stuffs.” He relates math abilities with the ability to solve engineering problems and to the ability to determine technological solutions to all kinds of problems. “I know that math is really key to the field [of engineering], and science you know, engineering is virtually the merge of math and sciences and practical problem solving.” Although he is not completely confident that his Calculus abilities are strong enough for certain engineering majors, he has great confidence that his basic math abilities will be good enough to solve engineering problems in his computer engineering major.