2018

Persistence and Characteristics of Calculus I Students in STEM Disciplines

Xiangming Wu

Follow this and additional works at: <https://researchrepository.wvu.edu/etd>

Recommended Citation

Wu, Xiangming, "Persistence and Characteristics of Calculus I Students in STEM Disciplines" (2018).
Graduate Theses, Dissertations, and Problem Reports. 7279.
<https://researchrepository.wvu.edu/etd/7279>

This Dissertation is protected by copyright and/or related rights. It has been brought to you by the The Research Repository @ WVU with permission from the rights-holder(s). You are free to use this Dissertation in any way that is permitted by the copyright and related rights legislation that applies to your use. For other uses you must obtain permission from the rights-holder(s) directly, unless additional rights are indicated by a Creative Commons license in the record and/ or on the work itself. This Dissertation has been accepted for inclusion in WVU Graduate Theses, Dissertations, and Problem Reports collection by an authorized administrator of The Research Repository @ WVU. For more information, please contact researchrepository@mail.wvu.edu.

Persistence and Characteristics of Calculus I Students in STEM Disciplines

Xiangming Wu

**Dissertation submitted
To the Eberly College of Arts and Sciences
At West Virginia University**

**Doctor of Philosophy in
Mathematics**

**Jessica Deshler, Ph.D., Chair
Edgar Fuller, Ph.D.
Karen Rambo-Hernandez, Ph.D.
Marjorie Darrah, Ph.D.
David Miller, Ph.D.**

Department of Mathematics

**Morgantown, West Virginia
2018**

**Keyword: Persistence, Attitudes and Beliefs, Perceptions of Pedagogies
Copyright 2018 Xiangming Wu**

ABSTRACT

Persistence and Characteristics of Calculus Students in STEM Disciplines

Xiangming Wu

The purpose of this dissertation is to investigate the relationships between student persistence and students' attributes or perceptions of instructional pedagogies, as well as to examine whether the identified relationships are moderated by three different instructional settings. Improving student persistence in science, technology, engineer, and mathematics (STEM) fields has been focused on by many researchers in mathematics education. A consistent STEM student enrollment in colleges/universities coupled with a high drop-out rate has been a striking issue. Many studies have been dedicated to investigating the factors that have play a role in this problem. Researchers have found that there are significant relationships among student persistence, students' attitudes and beliefs toward mathematics, and perceptions of pedagogies. However, the role course structures played in these relationships has not been focused on by many studies. In this dissertation, I replicated a national study titled *Characteristics of Successful Programs in College Calculus* (CSPCC) in three different Calculus I course settings to study the role of course structures in changes in students' attitudes and beliefs toward mathematics and in the relationships among persistence, attitudes and beliefs, and perceptions of pedagogies.

To examine the effect of three different course settings on student attributes toward mathematics including attitudes, beliefs, enjoyment, confidence, and desire for more mathematics, I surveyed 1051 first semester calculus students by utilizing a well-developed survey from the CSPCC study. Analysis of survey data with respect to student attributes revealed the learning experience in different course settings affected student attributes differently. In paper 1, I explored some significant differences and similarities in Calculus I student attributes among three different course settings, and I showed that these differences and similarities were affected by course settings, instead of student academic backgrounds.

In this dissertation I also examined a moderation effect of course settings on the relationships between student STEM persistence and student attributes or perceptions of pedagogies. In paper 2, I confirmed the relationships found in literature; but I also found the course structures moderated these relationships. The student confidence and the progressive teaching in one of three course settings moderated the relationship significantly.

In paper 3, I specifically focused on Calculus I students' major and career exploration by doing a case study in order to provide some focused insights to understand some parts of the STEM drop-out issue. I explored Calculus I student's characteristics of major and career decision making strategies, as well as their reasons for changing their planned major and career.

DEDICATION

To my family,

Ye Chen, Terrance Wu & Thomas Wu

ACKNOWLEDGEMENTS

First and foremost, I am most indebted to my advisor, Dr. Jessica Deshler for her continued encouragement and support over these last few years. It is a pleasure to work under your supervision. I greatly thank you for your advice for both my academic life and personal life. Without you, I indeed believe this dissertation could not have come about.

I also would like to take this opportunity to thank Dr. Edgar Fuller. Thank you very much being my co-adviser to help in any ways that you could. Especially, I appreciate very much your understanding and great support during data collection for my dissertation. I also feel grateful for the National Science Foundation grant that funded the research experience that you and Dr. Jessica Deshler provided to me.

Dr. Karen Rambo-Hernandez, thank you for teaching me many research and writing skills. I feel very grateful and joyful to have worked with you. I have become more confident in writing educational research papers after your supervision.

I would also like to thank my other committee members: Dr. Marjorie Darrah and Dr. David Miller, for their help during my studies.

And finally, I would like to thank the Department of Mathematics and Eberly College of Arts and Sciences at West Virginia University for providing me with an excellent study environment and financial support during my study as a graduate student.

Table of Contents

Chapter 1. Introduction	1
Background Study	1
1.1 Success rate comparison between Math 155 and Math 153/154 from fall 2008 to fall 2012	3
1.2 Success rate comparison between versions of Math 155	4
1.3 Success rate comparison after persisting into Calculus II between Math 155 and Math 153/154	7
1.4 Success rate comparison after persisting into Calculus II by each version of Math 155 ..	8
1.5 Rationale for CSPCC replication study	9
The CSPCC Study	10
A note on the analysis of historical data	14
Brief history of the Calculus I program in the local department	16
Literature Review	18
5.1 Introduction	18
5.2 Persistence Literature	19
5.3 Student's attitudes and beliefs	35
Theoretical Perspectives	39
Research Questions	42
Chapter 2. Methodology	45
Survey Instrument	45
Data Collection	45
Related Projects - Data Collection	48
Data Analysis	48
Chapter 3. Dissertation Papers	53
Paper 1: The effects of different versions of a gateway STEM course on student attitudes and beliefs	53
Abstract	53
Introduction	54
Background	54
Institutional Context	58

Students' Demographic Data	59
Students' Academic Backgrounds	60
Methods	62
Results	65
Discussion	75
Conclusion	79
Paper 2: The moderation effect of course structures on the relationship between persistence and students' attitudes and beliefs or perceptions of pedagogies	81
Abstract	81
Introduction	81
Literature Review	82
Methods	87
Results	92
Discussion and Conclusions	100
Paper 3: A Exploratory Study on Characteristics of Calculus I Students' Career Decision-Making Strategies	104
Abstract	104
Introduction	105
Literature Review	105
Current Study	106
Methods	107
Results	109
Conclusions	116
Acknowledgement	117
Chapter 4. Dissertation Conclusions.....	119
Chapter 5. Future Work	124
Chapter 6. Bibliography.....	126
Appendix A.....	142
Appendix B	157
Appendix C	168

List of Tables

Table 1. Enrolled Calculus I students by entry path from fall 2002 to fall 2012.....	1
Table 2. Student pass rates from fall 2002 to fall 2012	2
Table 3. Comparison of success rates between Math 155 and Math 153/154 from fall 2008 to fall 2012.....	4
Table 4. Success rates for the four versions of Math 155 from fall 2005 to fall 2012	6
Table 5. Comparison of success rates of Math 155 and Math 153/154 students in Math 156	8
Table 6. Success rates for four versions of Math 155 after entering Calculus II from fall 2005 to fall 2012	9
Table 7. Fall semester student success rates for Math 153, E, NE from 2011 to 2015	15
Table 8. Students' success rates for Math 154, E, and NE after entering Calculus II from 2012 – 2016.....	16
Table 9. Distribution of consented students.....	46
Table 10. Distribution of replicated CSPCC data.....	46
Table 11. Distribution of EAGER data.....	48
Table 12. Student Demographics for Fall 2015 by percentages	59
Table 13. Students' Academic Backgrounds	61
Table 14. Factors for analysis	63
Table 15. Changes in Sample Means of Students' Beliefs and Attitudes.....	67
Table 16. Change in Students' Confidence, Enjoyment and Desire for More Mathematics.....	71
Table 17. Normalized Descriptive for Confidence, Enjoyment and Background	73
Table 18. Correlation of Enjoyment and Confidence with Content Background Demographics	74
Table 19. Demographics of participants	89
Table 20. Correlation matrix of variables	92
Table 21. Students persistence predicted by students' attitudes and beliefs.....	93
Table 22. Students persistence predicted by students' perception of pedagogies	95
Table 23. Student's persistence prediction with moderation effects	97
Table 24. Students persistence predicted by moderation effects	99
Table 25. Cronbach's alpha of Question 1 to Question 8.....	108
Table 26. Sample mean comparison between factors of characteristics of career decision making	111
Table 27. Pre- and post-survey comparisons for reasons for change-population indicating major change intention.	112
Table 28. Switchers' reasons for changing major during pre- and post-survey by gender	115
Table 29. Switchers' reasons for changing major during pre- and post-survey by STEM classification	115

List of Figures

Figure 1. Tinto's integration model of persistence (Tinto, 1975, p. 42).....	40
Figure 2. Comparison on the relationship of attitudes and persistence at different level; and comparison on the relationship of enjoyment and persistence at different level.....	94
Figure 3. Comparison on the relationship of good teaching and persistence at different level; and comparison on the relationship of progressive teaching and persistence at different level.....	95
Figure 4. Moderation effect in engineering-based course on the relationship of confidence and persistence.....	98
Figure 5. Moderation Effects in two-semester Calculus I equivalent course and non-engineering course on the relationship of progressive teaching and persistence	100
Figure 6. Student responses to open ended question about factors affecting choice of major or career goals	110
Figure 7. Student responses to open ended question about attractiveness of major or career goals	110
Figure 8. Percentage of students intending to change major by survey response and actual switch rate of students	112
Figure 9. Percentage of students intending to change major by survey response and actual switch rate of students by gender.	113
Figure 10. Percentage of students intending to change major by survey response and actual switch rate of students by STEM classification.....	114

Chapter 1. Introduction

Calculus is a gateway course where students traditionally struggle; the purpose of this study is to determine how well one university's approach to teaching the course aligns with a national study of calculus effectiveness. This study analyzes relationships among students' attitudes and beliefs toward mathematics, perception of instructional pedagogies, and persistence in three different Calculus I instructional settings to gain an insight into factors that need to be considered in a future development of successful Calculus program.

Background Study

Calculus I has been traditionally offered every semester in the Department of Mathematics at West Virginia University (referred to as "local department" for the remainder of this document). From fall 2002 to fall 2012, the local department instructed 16,047 (no repeat students included, i.e., no double counts) Calculus I students. Students have entered Calculus I

Table 1. Enrolled Calculus I students by entry path from fall 2002 to fall 2012.

Entry path	Total
ACT/SAT/QRA	4,976
AP/Transfer credits	2,309
Completion of pre-requisite courses at WVU	9,400
Other	4,789
Total	21,474*

* This number includes all the enrollments, counting students each time they enrolled in the course and thus differs from the number in the preceding paragraph

through various paths: ACT/SAT mathematics score or local departmental placement exam score (Quantitative Reasoning Assessment - QRA), Advance Placement (AP) score or transfer credits, or completion of pre-requisite classes. Table 1 provides information on the numbers of students who used each path to enter Calculus I from fall 2002 to fall 2012.

Between fall 2002 and fall 2012, the local department dedicated significant resources to the development of the Calculus program including the design of different Calculus I versions for different audiences of students (based on declared majors). A short history of development of the program is presented in section 5 of this chapter. Currently, Calculus I is offered in several different options, but two are the main pathways for students to get through Calculus I in the local department. The first is a slower paced two-semester course with Precalculus content built into it for students ready for calculus content but not quite ready for the fast pace of a regular college calculus course, Math 153 and Math 154. The larger portion of student population in this course are engineering majors. In this course, students meet with their instructor three times per week in a lecture format class, and once per week in a ‘laboratory’ setting with a graduate student to work on activities in groups designed to support the development of concepts. This course has a class size about 80 students in both lecture and lab. The labs in Math 153 are

Table 2. Student pass rates from fall 2002 to fall 2012

Course	Enrollment	Pass Rate	Earned a grade of ‘A’ among passing students
Math 153/154 ^a	2593	39.65% (1028)	20.04% (206)
Math 155	14680	54.09% (7940)	25.58% (2031)

^a math 153/154 started in the fall 2008

computerized and part of the labs in Math 154 are computerized, part are still using pencil and paper. The second is the standard one-semester undergraduate Calculus I course, Math 155. This course has four different versions, and the specific details will be presented in section 1.2. Pass rates for Calculus I students from fall 2002 to fall 2012 (with a passing grade defined as a C or better) are presented in Table 2.

In fall 2013, for the purpose of gaining insight into students' achievement in Calculus I and Calculus II, I analyzed a dataset consisting of all Calculus I & II students' information including demographics and grades for the ten-year period from fall 2002 to fall 2012. The goals for this investigation were to compare:

- 1) student success rates in Math 155 and Math 153/154
- 2) student success rates in four different versions of Math 155
- 3) student success rates after persisting into Calculus II by the different entry paths
- 4) student success rates after persisting into Calculus II by each version of Math 155

1.1 Success rate comparison between Math 155 and Math 153/154 from fall 2008 to fall 2012

Since Math 153/154 started in fall of 2008, and my dataset ended in 2012 (when I started this work) I compared a four-year period of data instead of a ten-year period for this comparison. In this comparison, since the students enrolled Math 153 and 154 need to finish both Math 153 and Math 154 to be considered having completed Calculus I, the total enrollment for Math 153/154 (in Table 3) includes all students in both classes. However, the student success rate I used only included students who passed Math 154 with a grade of C or better. In the other words, a student who passed Math 153 with a grade of C or better but did not complete Math 154 in any subsequent semester was not considered as a passing student. As shown in Table 3, the number of students who completed Math 155 was about twice the number of students who completed

Math 153/154 from fall 2008 to fall 2012; and the success rate for Math 155 surpassed the success rate for Math 153/154 by 21.73%. Within the students who succeeded in both classes, the percentage of Math 155 students who received a grade of A in Math 155 was 9.67% more than that in Math 153/154. This is not surprising a result, because Math 155 students have a comparatively stronger mathematics background than Math 153/154 students, and deficiencies in mathematics background was the main reason for the separation of students.

Table 3. Comparison of success rates between Math 155 and Math 153/154 from fall 2008 to fall 2012

	Math 155	Math 153/154
Total Enrollment	5429	2593
Earned grade of A, B, C	61.38% (3329)	39.65% (1028)
Earned grade of A only	29.71% (989)	20.04% (206)

1.2 Success rate comparison between versions of Math 155

Due to the different demands of mathematics for different majors, starting in the fall of 2005 the local department began offering several versions of Math 155 instead of a single, traditional course. The engineering version (E) was offered for engineering majors such as chemical or electric engineering, etc. Three days per week students attend more traditional lecture format meetings with the instructor of record. This course has 40 students during the study period in both lecture and recitation. During non-computerized recitations two days per week, students work on activities led by graduate students that often align with content they are also learning in their introductory engineering courses and that maintain a high level of

computational complexity. The course focuses more on technical skill development and computational precision than on deeper conceptual understanding. Many of these classes are offered on the engineering school's campus, instead of near the Department's other classes. The non-engineering (NE) version was provided for non-engineering majors such as economics, English, chemistry, biology, etc. The format of the course incorporates a highly student-focused meeting with an instructor three times per week that incorporates group learning and other activities to develop strong conceptual understanding. These activities incorporate a more active learning approach where students develop concepts through guided activities. Summative assessments focus on these concepts and avoid complex numerical processes that would require a calculator. Students meet with graduate assistants twice a week for additional work on problem solving and homework. This course has 34 students in both lecture and recitations. The Honors version (H) was offered to students who were members of the WVU Honors College. (Note: their inclusion in this group did not mean that they were 'excellent' mathematics students, but 'excellent' students overall and had been accepted to a university-wide Honors program and could enroll in any course designated as such, including mathematics courses). This course is purely lecture based, and it has 24 students per section. The Emerging Scholars Program (ESP) version was started several semesters later and offered to underrepresented students at WVU, defined to be ethnic minority, female, first-generation, etc. and this course usually is about 20 students.

As shown in the Table 4, the success rate for Honors (80.37%) surpassed the success rate for other three versions of the course; followed by ESP with a success rate of 71.43%. The Honors class achieved the highest success rate as anticipated since students were expected to be

the strongest academically among the four groups. The ESP version was constructed as a small class, inquiry-based and met for one additional hour per week than most other versions so

Table 4. Success rates for the four versions of Math 155 from fall 2005 to fall 2012

	E	NE	Honors	ESP
Total Enrollment	3987	4991	219	84
Earned grade of A, B, C	51.24% (2043)	58.32% (2911)	80.37% (176)	71.43% (60)
Earned grade of A only	14.68% (300)	33.15% (965)	40.34% (71)	36.67% (22)

students received more attention from the instructors and had more interaction with the content. Traditionally, this group of students perform worse than the majority population. The special construction of ESP class is to help underrepresented students to be successful in their academic career. Therefore, the results shown in Table 4 could be used to support the continuation of the ESP Course at the calculus I level. Its effectiveness has been examined at the surface level (Deshler, Miller, & Pascal, 2016) and warrants further study.

I took a closer look at E and NE because these two courses are the most similar among four. Due to the difference in their purpose (goals, student population, etc.), professors may have different expectations of students in the two classes with respect to conceptual and procedural skills. Comparatively speaking, E is coordinated with a desired higher demand for the learning of computational skills than NE. Consequently, it was more difficult to earn a passing grade, and again to earn a very high passing grade. Therefore, it is not surprising to notice that, overall, NE

students were slightly higher achieving in terms of grades than E students. I anticipate there are more factors that affect these rates of success than strictness in grading and would like to explore these other factors. Additionally, the percentage of students who passed the course with a grade of A in NE was almost two and half times the percentage of students who earned the same grade in E, even though the overall success rate for these two courses only differs by 6.79%. We investigate next whether this trend in the difference in performance between the classes continues into the subsequent class, Calculus II.

1.3 Success rate comparison after persisting into Calculus II between Math 155 and Math 153/154

Students have three primary entry paths by which they can enter Calculus II (Math 156) in the local department - through successful completion of Math 155, through a successful completion of Math 153/154, and through a transfer of credit (including AP credit and transferred credit of a prerequisite course from another institution). Students must earn a C or higher either in Math 155 or Math 153/154 to register for a Math 156 class. Persistence from Calculus I to Calculus II is defined as succeeding in Calculus I then enrolling in Calculus II in any subsequent semester.

Students who completed either Math 155 or Math 153 and 154 from fall 2008 to fall 2012 were tracked into Math 156 to analyze success rates. Transfer grades were considered separately with special attention. I hypothesized that students who completed different pre-requisites for Calculus II would succeed differentially in the course.

As shown in Table 5, the significant gap in the student success rate between Math 153/154 and Math 155 shown in Table 3 (21.73%) decreases when examining Math 156 success (only a 10% difference). There is not as great a difference (though still a difference) in student

performance in Calculus II as there is in Calculus I, depending on the Calculus I class they took. On the other hand, the success rate with a grade of A still indicates a better performance of Math 155 students in Math 156 than the Math 153/154 students.

Table 5. Comparison of success rates of Math 155 and Math 153/154 students in Math 156

	Math 155 →Math 156	Math 153/154 →Math 156
Total Enrollment	1833	711
Earned grade of A, B, C	83.41% (1529)	73.42 % (522)
Earned grade of A only	31.92% (488)	20.88% (109)

1.4 Success rate comparison after persisting into Calculus II by each version of Math 155

The results from Table 4 illustrated that NE students earned higher grades than E students. We anticipated that the students from NE would do better than the students from E after entering Calculus II, however, the success rate for the students from E is 8.21% more than that of students from NE, in Calculus II, though the percentage of students who received a grade of A is about same (Table 6). The students from Honors and ESP maintained a high success rate of 83.92% and 79.07% respectively, in Calculus II.

As mentioned earlier, transfer students are considered separately. We are interested in how these students perform in Calculus II since we cannot judge their Calculus I performance or environment. As the shown in last column of Table 6, a considerably lower success rate occurred in the transfer group. However, it is worth noting that the transfer group has a very high percentage of students who received a grade of A. We see a polarization within the transfer group - very high performing (42.93% of those that passed earned an “A”) and very low

performing (only 31.64% of them passed the class) students - an interesting phenomenon for further investigation.

Table 6. Success rates for four versions of Math 155 after entering Calculus II from fall 2005 to fall 2012

	E →156	NE →156	Honor →156	ESP →156	Transfer →156
Total Enrollment	1690	1472	143	43	6928
Earned grade of A, B, C	88.17%	79.96%	83.92%	79.07%	31.64%
	(1490)	(1177)	(120)	(34)	(2192)
Earned grade of A only	31.28%	33.47%	55%	29.41%	42.93%
(Among passing students)	(466)	(394)	(60)	(10)	(941)

In conclusion, there appears to be a difference in student success rate between one-semester Calculus I and two-semester Calculus I with Precalculus, as well as among the different versions of the one-semester course. However, these findings alone do not provide a complete picture of the preparation of Calculus I students in any of the courses nor indicate any factors in students, instructors or instruction that might be the cause of the differences in student performance.

1.5 Rationale for CSPCC replication study

The above described historical data and thoughts about the incomplete nature of understanding of Calculus I instruction at the local department led me to my current project. Moreover, prior to this dissertation study, the local department has spent a large amount of resources to develop a successful Calculus I program, but there is not a rigorous study that has

been conducted to layout the accomplishments and to understand the effectiveness and the weaknesses of these five different versions of Calculus I. The findings led and helped me to conduct a formal research study to rigorously examine various characteristics of Calculus I instruction at WVU and their effects on student performance, success, attitudes and beliefs, especially with respect to the student's intention in pursuing a science, technology, engineering, and mathematics (STEM) major.

However, until I read about the national study, *Characteristics of Successful Programs in College Calculus (CSPCC)*, I did not have a good model for my study. The CSPCC study involved one-semester of data collection via surveys, and my replication study at WVU captures a 'snapshot' of Calculus instruction in the local department - a one-semester collection of data to fully understand the instruction and the students during that time.

The CSPCC Study

The *Characteristics of Successful Programs of College Calculus (CSPCC)* project is a national study, funded by the National Science Foundation (NSF) and conducted under the auspices of the Mathematical Association of America (MAA). In this section, I describe this study and summarize some of the results related to student persistence and student attitudes and beliefs towards mathematics (Bressoud, Carlson, Mesa, & Rasmussen, 2013; Ellis, Kelton, & Rasmussen, 2014; Sonnert, Sadler, Sadler, & Bressoud, 2015), and explain how my dissertation merges with the CSPCC study and why I believe this study provided an excellent model for my study.

From 2009 to 2014, a team led by David Bressoud and Marilyn Carlson conducted a national study of Calculus I instruction in U.S. colleges and universities, sponsored by the NSF (DRL REESE #0910240). They attempted to identify characteristics of successful programs in

college calculus. The description and results of the study can be found in the book *Insights and Recommendations from the MAA National Study of College Calculus* (Mathematical Association of America, 2015). The follow-up project, Progress through Calculus (PtC, NSF DUE #1430540) is currently investigating what does and does not work in the implementations of recommendations from CSPCC findings to improve student success in a Precalculus-to-Calculus II sequence. The goals of CSPCC were:

1. To improve our understanding of the demographics of students who enroll in calculus
2. To measure the impact of the various characteristics of calculus classes that are believed to influence student success,
3. To conduct exploratory case study analysis of exemplary programs to identify why and how these programs succeed,
4. To develop a theoretical framework that articulates the factors under which students are likely to succeed in calculus, and
5. To use the results of these studies and the influence of the MAA to leverage improvements in calculus instruction across the United States.

The study consisted of two phases. The first phase was the administration of five surveys to collect primary data including student demographics, attitudes and beliefs, high school preparation, students' and instructors' perception of instructors' teaching pedagogies, departmental preparations and supports. The surveys were sent to over 14,000 students at 521 colleges and universities, and 212 colleges and universities participated. These data were examined and used to determine which institutions had a successful program on several axes, including students' final grades, persistence, and attitudes and beliefs about mathematics. The second phase involved case studies. The study team visited 17 institutions that were identified as

successful. Case studies comprised focus group interviews, class observations, and interviews of many administrative and teaching staff at each institution.

Bressoud, Carlson, Mesa, and Rasmussen (2013) reported some standard statistics about student demographics, attitudes and beliefs, and STEM persistence for the sample in the CSPCC study. They found that 61% took a calculus class in high school, and 62% of those took an AP AB course, 13% took a BC course, and 34% earned a 3 or higher on AP exams. Students were confident with their preparation and abilities. However, their actual performance was lower than what they expected: one quarter of them did not pass their class, and the grade earned for those who did pass was much lower than anticipated. Moreover, with a pre- and post-surveys, Bressoud et al. (2013) reported that students experienced a significant decrease in levels of confidence, enjoyment and desire toward mathematics. These results are further confirmed by Bressoud (2015), and he suggests to high school teachers that there is no need to rush high school students into calculus, but should instead offer an alternative course in high school that focuses on strengthening students' understanding of algebra, geometry, trigonometry, and functional relationships while building problem solving skills would be very welcome.

Ellis, Kelton and Rasmussen (2014) specifically analyzed students' perceptions of twelve (12) instructors' pedagogical activities in teaching Calculus I. They compared the reported frequency of each of the 12 pedagogies among switchers, persisters, and converter. They noted that switchers and persisters had different perception of instructor's pedagogies. They concluded that these differences showed that the instructor's pedagogy is the main factor impacting students' persistence in Calculus I. In general, low levels of perception on specific activities are individually related to STEM persistence. Specifically, switchers reported low levels of activities showing students how to work specific problems, lecturing, preparing extra material to help

students understand calculus concepts or procedures, requiring students to explain their thinking on exams, and holding a whole class discussion. Moreover, the activities often considered as “innovative”, including explaining their thinking, having students give presentations, holding a whole-class discussion, and having students work with one another, were perceived to be discouraging for converters switching into STEM majors.

According to Johnson, Ellis and Rasmussen (2015), how instructors and students experience time constraints on covering amount of material is related to student persistence in a STEM major. Students found motivation difficult to go to a class where the instructor does not present materials in a stimulating manner, and is over-focused on getting students to memorize material, and does not communicate with students to make sure the presented materials are effectively understood by students.

Sonnert et al. (2015) performed an analysis of the factors of “good teaching” and “ambitious teaching.” The results show that how instructors teach affect students’ mathematics attitude. Specially, generally accepted “good teaching” (e.g. clarity in presentation and answering questions, useful homework) practices have the most positive impact, particularly for students with a weaker initial attitude. Use of educational technology (e.g. graphing calculators) has no impact on attitudes, except a negative effect on student attitudes when used by graduate student instructors. “Ambitious teaching” (e.g. group work, flipped reading) has a small negative impact on student attitudes, but enhancing attitudes for students who already enjoyed a positive attitude and in a large classroom environment. Ellis, Hanson, Nunez and Rasmussen (2015) analyzed the homework given to the calculus students and concluded three important aspects of homework, including structure, content, and feedback, that have impact on students’ attitudes, and in turn on students’ persistence. Specifically, they found that homework with more varied

structure, that included more content emphasizing skills as well as solving novel problems, and provided higher amounts of and frequency of feedback to students led to students tending to be more successful. Also, students felt positively towards conceptually driven homework, but their feelings were mixed or negative regarding the logistical aspects of online and group homework assignments.

Instead of examining the data at a national level, I examined data from three versions of Calculus I at one institution. I gave the same surveys used by CSPCC to the students during the fall 2015 semester. In this way, I can compare WVU's data to the national dataset which we have been provided. Hence, one of the goals of my current project is that the results of the study will contribute to complete a richer picture of successful college calculus programs and provide a better understanding of WVU's calculus offerings and the aspects of the programs that are and will be most successful.

A note on the analysis of historical data

I must note that the historical data may not accurately reflect current student performance. There was a significant time gap between the data collection for my study and the background data. The results of analysis of historical data could be unrepresentative to outcomes of current versions of Math 153/154 and the E and NE versions of Math 155. Since the fall of 2012, many modifications have happened in these classes. Math 153/154 and Math 155 NE have new course coordinators and there have been changes in structures of some of the courses. We also note that it is very difficult to compare the success of students in Math 153/154 to those in 155 as a single semester snapshot would capture students only halfway through the Calculus I curriculum in Math 153/154, but students in the Math 155 classes who would have completed the curriculum. In the background data (section 1), we used 'success' to represent the number of

students who started Math 153 and successfully passed Math 154 in a later semester. That is a more complicated set of data to work with than the pass rate data for a single-semester Math 155 class. Hence, the results presented in section 1 do not illustrate accurate outcomes for recent years (since fall 2012). Since the data for my dissertation were collected after the modifications,

Table 7. Fall semester student success rates for Math 153, E, NE from 2011 to 2015

Semester	Course	Earned grade of A, B, or C
Fall 2011	Math 153	75.65%
	NE	70.69%
	E	69.02%
Fall 2012	Math 153	73.48%
	NE	65.09%
	E	67.98%
Fall 2013	Math 153	77.04%
	NE	69.00%
	E	73.38%
Fall 2014	Math 153	57.22%
	NE	64.56%
	E	76.32%
Fall 2015	Math 153	72.66%
	NE	73.26%
	E	74.63%

and based on earlier data, I acknowledge that I should present more recent student outcomes to clarify any questions the readers might have about current performance of students in these courses. If we consider only a fall semester performance (usually the stronger students are enrolled in Calculus I in a fall semester), then we would compare only Math 153 students to Math 155 E and Math 155 NE. Table 7 shows that the success rate in Math 153 during fall semesters between 2011 and 2015 was higher than in E or NE in three of the five years.

Table 8. Students' success rates for Math 154, E, and NE after entering Calculus II from 2012 – 2016

	E →156	NE →156	Math 154 →156	^a Other → 156
Total Enrollment	1528	1173	839	742
Earned grade of A, B, C	87.24%	73.15%	78.31%	78.57%
	(1333)	(858)	(657)	(583)

^a Other includes the other two versions of Calculus I (H, ESP) and transfer students

By comparing Tables 7 & 8 to Tables 3 – 6, I believe I can claim that the historical data are still representative of student performance in E & NE. There is a significant difference in the Math 153/154 data presented between the two sets of tables (historical vs. more current data), which we acknowledge could be due to the combination of changes in the course and the difference in where students were in the timeline across the Calculus I curriculum (whether they had completed the entire course or only one semester of it).

Brief history of the Calculus I program in the local department

The design of the Calculus I program occurred over a decade in the early 2000s. Prior to this, in the late 1990s, Calculus I enrollment at the University was a small percentage of the

overall mathematics enrollment, but as this population began to grow so did concerns about the mathematical backgrounds of the students and their success in the course. By the early 2000s, low student success rates and differences of opinion on the necessary content and rigor in the course first led to a split of the course into two versions - one for engineering majors and one for the rest of the student population. At this time, the University's College of Engineering offered to support their students by aligning the content of other classes in that College with the mathematics content of the engineering version of the Calculus I course. The engineering students are provided with engineering-based application problems during recitations led by post-graduate students that often align with content they are also learning in their introductory engineering courses. The practice problems for students in the non-engineering version of the course are relatively more conceptual and application problems are not engineering based.

Shortly after splitting into these two versions of the course, student success and placement data was used to identify a distinct cohort of students who would have previously either not been able to directly enroll in Calculus I or who were at the highest risk of failing or withdrawing from the course. For this cohort, another course structure was developed that would allow them to learn the content from Calculus I over a two-semester time-period (instead of one) allowing for more in-depth coverage of core but troublesome calculus concepts with time to review pre-calculus content as needed. Students entering this course typically are at or above the level of precalculus but do not have the mathematical maturity to flourish in the pace of a one-semester course. The goal of this course was to establish a Calculus I entry point that would allow access to students who otherwise would not be able to enroll there due to lack of preparation or would likely not succeed in the traditional one-semester course.

Each version of the course has a coordinator who supervises the instructors in that course and whose philosophy about teaching and goals for the course drive their curricular decisions independent from the other courses, except for one item - all three courses use the same textbook. The textbook is used for the entire calculus sequence, and beyond Calculus I there is only one version of each course (Calculus II, Calculus III, etc.). The extent to which each course relies on the textbook is, however, up to the coordinator for that course. Each coordinator determines how the instructors and students spend their time during both lecture and recitation or lab hours.

Literature Review

For my dissertation, I have identified two relevant bodies of literature. The first one focuses on student persistence, the second one on the role of students' attitudes and beliefs toward mathematics.

5.1 Introduction

Given its great broad importance and utility in college/university education, the subject of Calculus I has gained attention in the field of mathematics education, and a significant amount of research has been conducted to study this subject with respect to a variety of aspects ranging from Calculus I curriculum reforms to the teaching and learning of specific topics in Calculus I (e.g.: functions, limits, derivatives, etc.). There are many reasons why mathematics education researchers have focused on Calculus I. Calculus I is considered by many as a gateway that students pursuing a STEM major must pass through to successfully pursue their degree programs. Thus, mathematics education researchers often consider Calculus I as a course that filters students in a STEM field. Due to its importance, researchers, educators and administrators alike feel that Calculus I should be well taught. Unfortunately, a recent study showed that almost

a quarter of the students in any given calculus class will not earn a passing grade (Bressoud, Carlson, Mesa & Rasmussen, 2013). Many students departing higher education state that a poorly-taught learning experience in an introductory course is a primary reason for leaving (PCAST, 2012; Hunter, Thiry, Holland, Harper, & Seymour, 2016), and Calculus I was among the courses most often cited. I was attracted by the literatures on student persistence (especially STEM persistence) as well as students' attitudes and beliefs toward mathematics; and the CSPCC project (section 2) is the most closely aligned to these ideas in the context of Calculus I.

5.2 Persistence Literature

Even though there is an historically high demand for STEM graduates to strengthen the national work-force (NSB, 2007; NRC, 2007, 2010; PCAST, 2012), studies show that the number of students pursuing a STEM major has remained constant at about 30% (Carnevale, Smith & Melton, 2011; Hurtado, Eagan, & Chang, 2010) and less than 40% of those actually complete a degree in a STEM field (PCAST, 2012). Many STEM intending students change their majors with researchers finding many reasons for their departure specifically including their Calculus I learning experiences (Seymour & Hewitt, 1997; Ellis, Kelton & Rasmussen, 2014; Litzler & Young, 2012; Soldner, Rowan-Kenyon, Inkelas, Garvey, & Robbins, 2012). National Center for Education Statistics (2008) reported that out of about 4 million 9th graders who entered high school in 2001, about 1.9 million of them went on to either a two- or four-year college four years later. However, less than 300,000 of them majored in a STEM field (including health sciences) and only about half of them graduated with a STEM degree at 2011. Education researchers have noticed the trend and have focused their research efforts on this problem. For instance, engineering fields are popular majors among STEM intending students and have been greatly focused on by many researchers. The National Research Council (2007, 2010) indicates

that there is a great need for engineering graduates to sustain the United States' competitive position in the global market. However, a study showed that students are most likely to drop out from an engineering major during the first two years of school (Litzler & Young, 2012). Froyd, Wankat, and Smith (2012) found a diminishing trend in engineering students' performance in a sequence of Calculus courses. They proposed that an engineering student's performance in the Calculus sequence is a good approximate prediction of the student's performance in an engineering major as well as of his/her persistence in engineering in general. This implies that a grade received in Calculus I plays a critical role on an engineering student's intention to continue in an engineering major.

Now, it is very clear that we need to examine the reasons students give for leaving STEM majors, and then proceed to address the issues in terms of teaching implications. There are many reasons why students are leaving (Seymour & Hewitt, 1997; PCAST, 2012). In their book, *Talking about leaving: why undergraduates leave the sciences*, Seymour and Hewitt (1997) revealed several important categories of reasons for why student's leave (a team lead by Seymour are currently investigating these categories again to examine if there have been some changes), and I will discuss them later in detail. These reasons are echoed by PCAST's (2012) findings focused on students leaving STEM degrees. Both remarked that poor learning experiences were the most common complaint. Results from the CSPCC national study showed that students' experiences in Calculus I have significant effects on decisions about pursuing a STEM major as well as their attitudes toward mathematics (Bressoud, Carlson, Mesa & Rasmussen, 2013). Others (Rasmussen & Ellis, 2013; Ellis, Kelton, & Ramussen, 2014; Rasmussen & Ellis, 2013; Toven-Lindsey et al., 2015) have also concluded that the instructional

experience of Calculus I is the primary reason why students are discouraged to continue in the Calculus course sequences.

Many studies have been devoted to investigating issues related to STEM student persistence, or equivalently, STEM student retention. By analyzing 191 educational research articles published between 1995 and 2008, Henderson, Beach, and Finkelstein (2011) identified four categories of current research on STEM disciplines: disseminating curriculum and pedagogy, developing reflective teachers, enacting policy, and developing shared vision; they remarked research needs to be focus on these categories, and any progress made in regards to these categories would benefit both student learning outcomes and student retention in STEM fields.

The term “student retention”, or equivalently, “student persistence” has appeared in many education journals. Students can persist in a major within a given university (persistence in major), or a student can change majors but persist within a given university (persistence in university), or a student can transfer to another institution but continue in the educational system (persistence in education). Seymour and Hewitt (1997) defined the term “switcher” “to include both leaving a declared S.M.E (STEM) major for a non-S.M.E (STEM) major, and declaring a non-S.M.E (STEM) major, despite an original intention to enter an S.M.E (STEM) major” (p.14); the term “persister” is defined to include all those non-switchers. Recently, Ellis, Kelton, and Rasmussen (2014) defined more terms specific to a student’s STEM intention: a “persister” is a student who declared and eventually graduated with a STEM major; a “switcher” is a student who originally declared a STEM major but graduated with a non-STEM degree; a “converter” is a student who did not declare a STEM major but did graduate with a STEM degree; a “culminater” is a student who did not declare a STEM major and eventually did not graduate

with a STEM degree. A broad definition of persistence is defined by falling within any of these categories.

Numerous studies have focused on studying the factors related to student retention (Tinto, 1975, 1997, 2004; Pascarella & Terenzini, 1980; Kuh et al., 2008). Tinto (2004) states that “interaction across academic and social geography of a campus shape the educational opportunity structure ... and ... both student learning and persistence” (p. 92). According to Tinto’s framework of persistence (1975) and the persistence framework developed by Graham, Frederick, Byars-Winston, Hunter, and Handelsman (2013), satisfaction in the integration of social and academic life on a campus including the classroom environment has a significant impact on persistence. In other words, these two frameworks both asserted that persistence will naturally occur when a student’s academic and social norms are greatly satisfied by interacting with academic and social norms provided by the department and broader institution. Tinto (2004) highlights that this satisfaction is critically important to students during freshman year, because this is the time when their “membership in the communities of the campus is so tenuous” (p. 3). Therefore, their persistence is influenced by student-level and institutional-level factors or a combination of both. Correspondingly, there is a mix of individual and institutional reasons that explain persistence. The factors at the institutional level do not impact as directly as those at the student-level the overall (i.e. all the course and programs) student persistence at an institution.

Researchers in higher education have explored institutional-level persistence since the 1970s. Tinto’s (1975) interactionist theory and Bean’s (1980) student attrition model both argued that a student’s experience within an institution has a positive influence on persistence. They, as well as many others (Lau, 2003; Jensen, 2011) claimed that an overall positive satisfaction with an institution may keep student retention high. Tinto (1993) and Graham, et al. (2013)

emphasized the importance of social and academic integration on persistence. According to Tinto (1975), persistence occurs when students are socially and academically integrated in the institution; student persistence is viewed as a function of the dynamic relationship between the student and other actors within the institutional environment, including the classroom environment. Tinto (1975) asserts that the more a student's experiences serve to integrate the student socially and intellectually into the life of the institution, the more likely the student is to persist. Astin (1993) contends that the student normative (Ethington, 2000) context of an institution, defined as peer group perceptions and attitudes within the institution, have an influence on student persistence. Specifically, he discussed how institutional characteristics such as popularity, a positive faculty environment, and freedom of curricular choices impact student retention. Studies (Astin, 1997; Dey, 1990; Kamens, 1971) have made an effort to examine the influence of differences between institutions on persistence. Kim, Rhoades, and Woodard (2003), Marcus (1989), Saupe, Smith, and Xin (1999), and Sjoberg (1999) found that a high institutional reputation, a high standard of selecting students and the size of the student population positively influenced persistence. Kamens (1971) found the ratio of students to instructors plays a role on student persistence. For instance, a lower student-teacher ratio encourages students to continue their education, because students believe that they would have more opportunities to gain support from instructors. Thomas and Bean (1988) found that institutional expenditures influence persistence; they asserted that higher expenditures on student financial aid may help improve the retention of students directly in STEM programs.

Compared to institutional-level factors, individual-level (student level) factors that affect persistence have received more attention in recent educational research. For example, in their book, *Talking about Leaving: Why Undergraduates Leave the Sciences*, Seymour and Hewitt

(1997) categorized these factors into 5 categories: (1) choice, preparation, and leaving STEM, (2) the learning experience in STEM major, (3) issues of gender, (4) career and lifestyle, time and money, and (5) issues of race and ethnicity. These five categories cover most of the topics in recent research on student persistence in STEM courses and programs.

5.2.1 Choice, Preparation, & Leaving

Many studies have shown that students' reasons for choosing a STEM major and students' preparation have an indirect effect on persistence (Bressoud, Carlson, Mesa, & Rasmussen, 2013; Ellis, Kelton, & Rasmussen, 2014; Seymour & Hewitt, 1997; Tinto, 2006; Brow et al. 2008). In the "choice model" of Social Cognitive Career Theory (SCCT) developed by Lent, Brown, and Hackett (1994), how people choose a career is related to persistence. By using the SCCT choice model, Lent et al. (2003) showed that perceived contextual supports (such as peer approval, access to the scholarship funding) and barriers (such as family disapproval, financial concern) on the choice-making affect engineering students' persistence in an engineering major. Seymour and Hewitt (1997) and Hunter, et al. (2016) summarized some reasons and motivations for initially entering a STEM major: the active influence of others, intrinsic interest, altruism, materialism and pragmatism, and gender differences. Many switchers, especially female switchers, initially chose to major in STEM based on the active influence of others such as friends, parents, and high school advisors, and consequently, they have a higher likelihood to switch out (Lent et al. 2005). Seymour and Hewitt (1997) and Elkins, Braxton, and James (2000) identified different groups of switchers based upon the reasons of choosing a STEM major. They found that some switchers entered a STEM major because of an intrinsic interest in the discipline or a leading career fields. They also identified a group of switchers who entered a STEM major because of a commitment to a wider social purpose such as promotion of

peace, protection of the environment, etc. The third one they identified is the group of switchers who chose a STEM major due to a desired level of remuneration and prestigious career paths. The above-mentioned switchers likely do not understand what is entailed in choosing a STEM major or what they can do with these majors, meaning that they do not have a clear self-identity in respect to the means of STEM. Consequently, once they encountered some “natural ‘hardness’ of sciences” (Seymour & Hewitt, 1997, p. 88), they are more likely to switch out of a STEM major due to a lower commitment.

Students’ preparation is another factor that impacts persistence, even though this is not a major factor cited by switchers in their decision to switch out and the direction of the impact of preparation depends on the type of preparation. Tinto (2006) indicated there is not a direct relationship between college retention outcomes and academic aptitude (general cognitive ability and high school performance). Brown et al. (2008) also showed that the students’ preparation (using high school GPA as factor) does not directly affect students’ retention, rather self-efficacy beliefs and goals are much more related to persistence.

Ellis, Kelton, and Rasmussen (2014) found that a “student who took no Calculus in high school or AP Calculus BC are least likely to switch out of STEM intention and students who took non-AP calculus in high school are the most likely to switch” (p. 10). Most of the switchers believed they were well prepared for a STEM major. In summary switchers made their choice to leave STEM not based on reasons directly connected with the nature of the academic work entailed in the majors they chose. This is a notable difference between switchers and persisters.

5.2.2 Learning Experiences and Teaching in STEM majors

The most significant factors that impact persistence are learning experiences (Seymour & Hewitt, 1997; Hunter, Thiry, Holland, Harper, & Seymour, 2016). They summarized factors that

contribute to students' learning experiences in the context of STEM majors including the 'hardness' of science, significance of grades, competitive culture, weed-out tradition, unsupportive culture, teaching and learning, and loss of interest and the appeal of other majors. Among these factors, the learning experiences related to teaching is the one that has been mostly focused and studied (Sonnert, Sadler, Sadler, & Bressoud, 2015; Ellis, Kelton, & Rasmussen, 2014; Soldner, Rowan-Kenyon, Inkelas, Garvey, & Robbins, 2012). This is not to say other factors are not important, just that many conducted studies (based on the literatures I found) that investigate student attrition have not considered them significantly since students who switch out STEM field have not cited them as significant reasons.

Seymour and Hewitt (1997) categorized and ranked the reasons that students indicated for switching out of STEM majors related to learning experiences, and unsatisfactory experience with poor teaching is ranked the highest. The results showed that 90% of students who switch out said they switched out because of a concern about the poor quality of teaching including the absence of faculty-student interaction, lack of preparation and organization on the part of the instructor and dryness of presentations.

In one study, Atadero, Rambo-Hernandez, and Balgopal (2015) found a positive relationship between engineering students' intention to persist and content knowledge demonstrated by an instructor in a classroom. In addition, the National Science Board (2007) noted a heavy emphasis on fundamental mathematics and science courses at the beginning of engineering programs; and as a consequence, this emphasis leads to student attrition from engineering. Reforms have been aimed at improving the skills and qualities that engineering graduates need (National Research Council [NRC], 1995; National Academy of Engineering [NAE], 2004, 2005) with an ultimate goal of improving persistence. One popular method is

project based learning (PBL) which has been shown to have a positive effect on engineering students' persistence (Graham, 2010; Kolmos & Graaff, 2014; Litzler & Young, 2012; Atadero, Rambo-Hernandez, & Balgopal, 2015).

In a study on college calculus students' attitude toward mathematics, Sonnert et al. (2015) performed an analysis of the factors of "good teaching" and "ambitious teaching." The results show that instructors' teaching affects students' mathematics attitude; specifically, they found that

"instructors who employ generally accepted 'good teaching' practices (e.g. clarity in presentation and answering questions, useful homework, fair exams, help outside of class) are found to have the most positive impact [in students' learning] particularly with students who began with a weaker initial attitude.... 'Ambitious teaching' (e.g. group work, word problems, 'flipped' reading, student explanations of thinking) has a small negative impact on student attitudes, while being a relatively more constructive influence only on students who already enjoyed a positive attitude toward mathematics and in classrooms with a large number of students." (p. 1).

A notable number of switchers also experienced an un-supportive learning environment where instructors are hard to approach with an unwillingness to provide assistance on learning and give a weed-out talk at the very beginning of the course (Seymour & Hewitt, 1997; Hunter, Thiry, Holland, Harer, & Seymour, 2016). Both switchers and persisters specifically criticized the instructor's pedagogical techniques of teaching. The most common ones are poor preparation of the lecture, a lack of sequencing or coherence on material, and little attempt on checking students' understanding (Seymour & Hewitt, 1997; Hunter, Thiry, Holland, Harer, & Seymour, 2016).

Ellis, Kelton, and Rasmussen (2014) specifically analyzed the difference between students' and instructors' perception of instructors' pedagogical activities in teaching Calculus I, and concluded that the instructor's pedagogy is the main factor impacting students' persistence in Calculus I. Students indicated that instructors did not display an understanding of the relationship between the amount of material to teach/learn and the constraint of time allotted to do so. According to Johnson, Ellis, and Rasmussen (2015), how instructors and student experience time constraints for teaching/learning a given amount of material is related to student persistence in STEM.

5.2.3 Issues of Gender

The interaction of gender and persistence is another factor that has been greatly studied (Ellis, Fosdick, & Rasmussen, 2015; Fennema & Sherman, 1976; Graham, Frederic, Byars-Winstrom, Hunter, & Handelsman, 2013; Griffith, 2010; Wolniak, Mayhew, & Engberg, 2012). Many education researchers have been interested in identifying and articulating factors that explain the disparity in gender representation and persistence in STEM (Fennema & Sherman, 1976; Griffith, 2010; Good, Rattan, & Dweck, 2012). Women are seen as minor participants in the STEM major (Seymour & Hewitt, 1997; Griffith, 2010; Ellis, Fosdick, & Rasmussen, 2015; Good, Rattan, & Dweck, 2012). There are fewer women than men pursuing education in STEM fields in college; and among those that do, a larger percentage choose to leave (NSF, 2007). The picture of women's participation in STEM is very puzzling. There is consistent evidence that women in STEM majors have higher GPAs than men (Islam & Al-Ghassani, 2015; Lindberg, Hyde, & Peterson, 2012), and the same has been found specifically in mathematics classes, both anecdotally and quantitatively (Burroughs & Deshler, 2013; Deshler & LaClair, in preparation). However, the persistence rate in national samples of STEM majors for women is far lower than

that of men's (Stenta, Elliott, Matier, Scott, & Adair, 1990; Bressoud, Mesa, & Rasmussen, 2015). Such a picture attracts much attention from education researchers. Before the 1970s, female student persistence was almost entirely caused by gender discrimination; women were denied entrance to STEM fields (Anderson, 1995). Since the 1970s, women have gained access to many STEM fields, but there are still many qualified women choosing to leave science (NSF, 2007; Seymour & Hewitt, 1997). Education researchers have identified many factors to explain the lower persistence rate of female students. Socializers, including teachers, parents, and guidance counselors, have played a negative role in young women's decisions of career; they are often less supportive to women interested in STEM (Seymour & Hewitt, 1997; Farmer, 1997). Classroom observations have shown that STEM teachers tend to be less supportive by providing fewer opportunities for learning and less praise to female students (Sadker, Sadker, & Zittleman, 2009). As a consequence, women suffer from lack of practice and the prevailing cultural attitudes and are put at a greater disadvantage in college (Carlone, 2004).

Women in STEM often feel that they are isolated, experiencing the 'chilly climate' (Shakeshaft, 1995; Griffith, 2010), a general feeling of decrease in interest, aspirations, participation, etc., in STEM fields. Good, Rattan, and Dweck (2012) found that students' persistence can be affected by a sense of belonging, and women tend to have a reduced sense of belonging due to their own fixed intelligence mindset coupled with gender stereotyping in the classroom. This has been cited as a major reason for females to leave STEM (Seymour & Hewitt, 1997; Shakeshaft, 1995). Researchers have shown that the presence of certain environmental factors, such as the representation of females and minorities in graduate programs, can increase the rate of female students' participation and success in STEM (Griffith, 2010). Other factors such as a weed-out system (an instructor giving a discouraging speech at the beginning of class

to push some students out) and a difference in perception of grades (how a student evaluates the meaning of his/her grades) (Seymour & Hewitt, 1997; Farmer, 1997) play a significant role in female student persistence in STEM fields.

Specific to Calculus I, Ellis, Fosdick, and Rasmussen (2015) identified a remarkable relationship between gender, switching, and mathematical confidence. They found that female students have a significantly lower level of desire to take Calculus II after taking Calculus I, because they “do not believe [they] understand the ideas of Calculus I well enough to take Calculus II”. They suggest the differences in confidence as a possible factor explaining the lower rate of persistence among female students in STEM. Ellis and Cooper (2016) also found that unfriendly teaching practices (such as teachers not being personable) can increase the chance of a female student having a fixed intelligence mindset, resulting in a decreased desire to persist in STEM.

5.2.4 Career Interest and Lifestyle, Time and Money

Seymour and Hewitt (1997) emphasized that students’ concerns about future career and lifestyle with a STEM major and the amount of time and money spent on a STEM major is another factor contributing to a student’s decision about persistence in a STEM major. In a study, Valentino, Moller, Stearns, and Mickelson (2015) found that a concern for the potential inflexibility of one’s future career is associated with a decreased likelihood of majoring in the “hard” STEM fields (physical sciences, engineering, and mathematics). In the “interest model” of SCCT (Lent et al. 1994) they indicated that how people developed their career interest and educational interest is related to persistence. Just like me, readers might never have thought that the length of completing a STEM major could be a factor influencing STEM departure. Some switchers left the STEM field and switched to an MBA program, which only (usually) requires 2

years to complete, because they think an earlier graduation from college would allow them to make more money by starting their career earlier (Shapiro & Sax, 2011).

With respect to future career and lifestyle after completion of a STEM degree, many switchers indicated their original major “to be unfulfilling, to lack worthwhile purpose, and to limit the possibility of full participation in family and social life” (Seymour & Hewitt, 1997, p. 228). Seymour and Hewitt (1997) and Xie, Fang, and Shamuman (2015) pointed out that some switchers, especially female switchers, believe it is hard to achieve a satisfying career and lifestyle within STEM fields, because they have heard stereotypes from others about the work contexts one could expect in professional science and engineering jobs, and about the kind of person one must become to do them. Consequently, they are scared and discouraged to continue in STEM fields. There is available financial aid to support education, but there is also a declining public and family financial support system available for undergraduate education as pointed out by Mortensen (1995) and National Center for Education Statistics (2013). As a consequence, universities and colleges have sought to cover this loss by increasing tuition and fees. This increase has put a burden on students (and students’ family), and then consequently pushed out some students from a STEM field (Seymour & Hewitt, 1997; Eagan, Hurtado, & Chang, 2010).

5.2.5 Issues of Race

Another important factor impacting student’s retention comprises issues of race. Studies have shown that the loss rate of students of color in STEM is the highest. In a study of national data for the 1980s, Morrison and Williams (1993) indicated that 35.6% of students of color entering engineering programs completed degrees in that field, compared with 68.4% for white students. The situation is no better in the sciences. As stated by Seymour (2002), “sixty-five percent of students of color entering science or mathematics left their major, compared with 37%

of white students” (p.80). Over the past 20 years, considerable efforts have been put into the recruitment and retention of students of color in the sciences. The enrollment of students of color in STEM fields has increased dramatically (Astin, 1993; PCAST, 2012) in recent years. However, the outcome in terms of retention for students of color is very discouraging: attrition rates remain unchanged (Brown, 1994; Science, 1992; PCAST, 2012; Sithole, Chiyaka, McCarthy, Mupinga, Bucklein, & Kibirige, 2017; NSF, 2014) and losses of these students are the greatest (Ware, Steckler, & Leserman, 1985; Tinto, 1993; Sithole, Chiyaka, McCarthy, Mupinga, Bucklein, & Kibirige, 2017).

Explanations for the failure of students of color to remain in STEM majors are somewhat patchy, and the relative importance of factors is unclear; however, most of the explanations emerged from a presumption of racial and ethnic difference in individual motivation (Seymour & Hewitt, 1997; Good, Rattan, & Dweck, 2012). For example, Treisman (1992) asked over 1,000 STEM faculty members to explain why they thought students of color were at greater risk of leaving their majors than white students. The most frequent of the theories that emerged posited ‘a motivation gap’ between white and Asian-American students, and students of color—who were assumed to be less motivated. By comparing the reasons for switching out between students of color and white students, Seymour and Hewitt (1997) and others (Chang, Sharkness, Hurtado, & Newman, 2014; Higher Education Research Institute, 2010) found that students of color are more likely switch out of STEM for the following reasons: initially unthoughtful reasons for their choice of a STEM major (34% compared with 6.1%), conceptual difficulty with one or more STEM subject(s) (30.8% compared with 5.3%) and inadequate high school preparation in basic subjects and study skills (25% compared with 10.7%). By contrast, white students more commonly cited the following as factors in their switching decisions: lack or loss of interest in

their STEM major (48.9% compared with 28.9%), poor teaching by STEM faculty (42% compared with 21.2%) and curriculum overload and fast pace (41.2% compared with 19.2%).

As mentioned earlier, an inappropriate choice of a STEM major is a factor that prompts students to switch out and this is especially true for students of color (Seymour & Hewitt, 1997; Espinosa, 2011). Some students of color were misguided when choosing a STEM major during recruitment and had insufficient interest, preparation or understanding; some black students had been actively recruited and offered scholarships, and these were powerful inducements, even for students who were unsure about what this choice would require. Families and communities also played a significant role in encouraging students of color to make choices that reflected social rather than personal career goals (Seymour & Hewitt, 1997). For example, many students of color were encouraged to choose a particular STEM major by families and schools because of job security; many Hispanic students chose an engineering major because this major was seen in their community as synonymous with success and Asian-American students choose a major to respect their parents' wishes and a strong desire to realize them.

Inadequate high school preparation is another reason why many students of color chose to leave STEM fields (Seymour & Hewitt, 1997; Treisman, 1992). As Treisman's (1992) survey indicated, many STEM faculty members perceived non-Asian students of color as insufficiently prepared for college-level STEM work, and this impression was confirmed by those students of color who started to believe that they were much less prepared than many white peers soon after entry to their first STEM classes. Some students of color believed they were too deficient in science and mathematics preparation to do well in college, so they left STEM fields before learning whether or not they could actually have surmounted their difficulties. Some students of color found they were over-confident after entering a STEM major in college due to an

inadequate academic preparation or an inflated view of their readiness to undertake the level of work required (Bressoud, Carlson, Mesa, & Rasmussen, 2013).

There are unique problems which cause the loss of students of color that are not generally shared by white males. These problems are derived “from conflicts between cultural values, family roles, educational socialization, community obligations and career expectations on the one hand, and the values and demands of college science and engineering on the other” (Seymour & Hewitt, 1997, p. 388). For instance, Asian-American, Native American and Hispanic students are less likely to question grades, because to do so over a personal achievement is not a respectful action towards elders and black students from inner-city areas have different attitudes about what it means to be a black STEM major from black students from upwardly-mobile black professional families (Seymour & Hewitt, 1997). Some students of color’s educational motivation were highly reliant upon their relationship with particular teachers, so they have not learned to use a peer study group. In other words, some of them received an intensified supportive learning experience from particular teachers during their previous study (for example, in high school), so they did not have or had very little learning experience with peers because they did not have the opportunity to do so. As a result, when they entered a university where they most likely will not have such supports from teachers, their response to the first experiences of objective grading in a STEM class are unfair and discriminatory (Seymour & Hewitt, 1997). There are many other examples for those conflicts, and those conflicts can have negative consequences for the success of students of color in STEM majors.

5.3 Student's attitudes and beliefs

In order to have a complete picture of student success in calculus, we must examine students' attitudes and beliefs toward mathematics, including confidence and enjoyment, because much of the research literatures have conclusively shown that students' beliefs and attitudes toward mathematics are strongly correlated with achievement in mathematics classes and students' (STEM) persistence (Pajares & Miller, 1995; Carlson, 1999; Schommer-Aikins, Duell, & Hutter, 2005; Tinto, 1975, 1997, 2004; Grahma, Frederick, Byars-Winston, & Hunter, 2013; Stolle-McAllister, Domingo, & Carriollo, 2011; Matsui, Liu, & Kane, 2003; Summers & Hrabowski, 2014; McLeod, 1992; Cobb, 1986). These literatures overwhelmingly showed the important role of students' beliefs and attitudes towards mathematics on performance and achievement in the study of mathematics as well as on student persistence.

According to Leder and Forgasz (2002), there is not a solid or common definition of 'belief' or 'attitude' since these terms "are not directly observable and have to be inferred, and because of their overlapping nature" (p.96). Other researchers hold that it is neither possible nor necessary to unify these different concepts of attitude and belief since different research problems can require different definitions (Hannula, 2012; Lewis, 2013). Despite the lack of agreement about the definitions of attitude and belief, there are several widely accepted definitions. In this study, I adopt the structure formulated by Fenneman and Sherman (1976), and the definition of attitude and belief, specifically including enjoyment and confidence, in their work. Fenneman and Sherman (1976) formulated the definition of attitude(s) towards mathematics as the positive or negative emotional disposition toward mathematics, and the definition of belief(s) towards mathematics as one's psychological acceptance of the truth and value of mathematics and learning of mathematics including the usefulness, relevance and worth

of mathematics in their life now and in the future. With these definitions, enjoyment refers to the degree to which students enjoy working mathematics and mathematics classes, and confidence refers to students' confidence and self-concept of their performance in mathematics. Structurally, I note that within psychological studies (Main, 2004), the notion of beliefs and values are considered precursors to attitude and that it is the latter that constitutes a predisposition to action. The definitions of Fenneman and Sherman align with this structure in the sense that a student's beliefs about mathematics will inform their attitudes by contributing to the positive or negative emotional framework for engaging in mathematical practice.

Pajares and Miller (1995) collected 391 students' responses to various types of self-efficacy judgments, and then students were asked to solve the problems that students had been assessed with their self-confidence. Authors found that self-efficacy and self-confidence were strongly correlated with student's success in problem-solving. By investigating student's beliefs and behaviors using the Views About Mathematics Survey (VAMS), Carlson (1999) proved that students who succeed in mathematics displayed high levels of enjoyment (and persistence) of mathematics. Carlson, Buskirk, and Halloun (1998) also studied undergraduate mathematics students' beliefs by using the VAMS, and concluded that a student's achievement is significantly correlated with self-confidence and expert-like mathematical beliefs, and students who experienced a high level of self-confidence were much more likely to track their study of mathematics. Schommer-Aikins et al. (2005) investigated 1269 middle-school students' epistemological and problem-solving beliefs and administered a test of mathematical problem-solving ability. The results showed that a student, who had a stronger belief in the usefulness of mathematics and lesser belief in "quick/fixed" learning of mathematics actually performed better in problem solving and conveyed mathematical ideas more efficiently. In addition, they also

suggested that beliefs are a good prediction of overall GPA in mathematics. Their findings are consistent with other prior works (Schommer, Calvert, Gariglietti, & Bajaj, 1997), which illustrated that a belief in quick learning has a negative correlation with academic performance.

Hembree (1990) and Ashcraft and Krause (2007) studied the role of anxiety in developmental mathematics students' course achievement. They argued that anxiety in particular interacts strongly with mathematics performance by inhibiting working memory and creating a cycle of difficulty for students. This cycle can be especially damaging to students in developmental courses due to the challenge already presented by the students' backgrounds. Also, as argued by Goldin (2004), nervousness and anxiety can trigger the activation of psychological defenses, which can weaken students' reaction of curiosity and a sense of interest in mathematical problems. He suggested that the use of problems should be appropriately placed to help students develop appropriate responses to feelings of frustration and impasse, so that student would gain exploratory behaviors.

Beliefs and attitudes are believed to have a significant impact on problem-solving behavior. Schoenfeld (1992) argued that many students believed that mathematics problems are straightforward applications of an algorithm. As a result, when asked how many buses were needed to transport a certain number of people, many students would provide an answer like "31 remainder 12" (p.71). In the process of developing their *multidimensional problem-solving framework*, which consists four phases – orientation, planning, executing, and checking, Carlson and Bloom (2005) revealed the importance of beliefs and attitudes, such as strong curiosity and high interest, feelings of intimacy, ownership of the problem, beliefs about the nature of mathematics, feelings of mathematical integrity and confidence in their mathematical abilities. These beliefs and attitudes were integrated together to affect problem-solving behaviors.

Therefore, researchers (Carlson & Bloom, 2005; Carlson, Bloom, & Glick, 2008) have recommended that teachers should provide explicit scaffolding and attention to help students develop productive mathematical beliefs. Particularly, they thought that teachers have responsibilities to help students manage emotions that occur during problem solving, arguing that “students should adopt the belief that frustration, disappointment, and elation are all natural responses to the problem solving process” (p. 286).

According to the persistence frameworks developed by Graham, et al. (2013) and Tinto (1975, 1997, 2004), attitudes and beliefs are critical requirements for STEM persistence. They argue that confidence and motivation are important factors associated with student persistence of STEM major. Indeed, researchers have revealed that attitudes and beliefs play a very important role in student persistence (Graham, et al., 2013; Stolle-McAllister, Domingo, & Carriollo, 2011; Matsui, Liu, & Kane, 2003; Summers & Hrabowski, 2014; McLeod, 1992; Cobb, 1986). Specifically, many of these results show that non-cognitive factors such as motivation, interest, confidence, and beliefs are potentially important to STEM attrition (Burtner, 2005; Chang, Eagan, Lin, & Hurtado, 2011; Espinosa 2011; Price, 2010; Seymour & Hewitt 1997; Schoenfeld, 1989).

In order to accurately assess students’ beliefs and attitudes, various instruments have been developed to examine dimensions of the affective domain in mathematics. In addition to the VAMS described above (Carlson, Buskirk, & Halloun, 1998), the Abbreviated Mathematics Anxiety Rating Scale (AMARS) originated from Richardson and Suinn’s Mathematics Anxiety Rating Scale (MARS) (1972) and was developed and validated by Alexander and Martray (1989) to diagnose and help treat mathematics anxiety. The Fennema-Sherman Mathematics Attitude Scales instrument (Fennema & Sherman, 1976) was designed to gather information about

learning of mathematics regarding gender; it is also used to determine factors that influence the decision to take mathematics courses beyond the required minimum.

The studies cited above conclusively proved the important role of attitudes and beliefs in student development in mathematics, because of their strong correlation with achievement and influence on behavior and on students' persistence. Further, as demonstrated by Sonnert et al. (2015), the teaching and classroom structure are also very influential to students' beliefs and attitudes. Thus, as researchers and teachers, we have the responsibility to find and document teaching strategies that will positively develop and improve students' beliefs, and then disseminate the most productive approach to be used in classroom. I hope my study will contribute to the literature by investigating the effect of the three versions of teaching on student attitudes and beliefs toward mathematics, as well as performance and persistence.

Theoretical Perspectives

By focusing on student retention, Tinto (1975, 1997, 2002) developed a theoretical model of student dropout from higher education – an integration model of persistence (Figure 1). In the model, he suggested that student retention is not a random phenomenon, but it can be predicted. He distinguished several categories of dropouts: involuntary, voluntary, transfer or temporary, and permanent. The involuntary dropout refers to the dropouts resulting from academic failures. The voluntary dropout results from other factors such as a low initial level of goal commitment. The transfer or temporary dropouts was used to group the students who dropped out from higher education because they are in a transition for re-entrance such as a transfer to another university. The permanent dropout category was defined to organize those who decide to drop out from higher education and not return. In his integration model of persistence, Tinto argued that students' level of commitment to an institute was affected by their experiences in both the

academic and social systems of the institute, and these commitments are essential and direct predictors of student retention. He also concluded that “choices of curriculum structure...and pedagogy invariably shape both learning and persistence of campus.” (Tinto, 1997, p. 620). Tinto (2004) states that “interaction across academic and social geography of a campus shape the educational opportunity structure ... persistence, a satisfaction in the integration of social and academic life on a campus including class environment has a significant impact on persistence. In other words, persistence will naturally occur when a student’s academic and social norms are greatly satisfied by ... both student learning and persistence” (p. 92). He highlights that this match is critically important to students during the freshman year because this is when their “membership in the communities of the campus is so tenuous” (Tinto, 2004, p. 3). In the United States, most students, especially STEM intending students, take Calculus I during the first year in college. Thus, the experiences they are exposed to in calculus will play a role in a student’s decision to persist in their intended majors.

Figure 1. Tinto's integration model of persistence (Tinto, 1975, p. 42)

For Yackel and Cobb (1996), students' mathematical learning at the classroom level occurs in the social context of the classroom. They noted an equal emphasis on psychological and social processes for students' learning. They believed that "mathematical learning is both a process of active individual construction and a process of acculturation into the mathematical practices of a wider society" (p. 460). This point of view is often referred to as the emergent perspective (Cobb & Yackel, 1996). This perspective coordinates between constructivist accounts of individual psychological development and sociocultural accounts of growing participation in communities of practice. They suggest that the students' development at the classroom level is aligned with a lens of a social-constructivist perspective, which claims that the individual's development was stimulated and interacted with in a social context (Ernest, 1999). Cobb and Yackel (1996) state that there is an existence of a reflexive relationship between classroom social cultures and students' development, and such reflexive relationships assume that "neither an individual student's mathematical reasoning nor the classroom microculture can be adequately accounted for without considering the other" (Cobb & Bauersfeld, 1995, p. 9-10). Thus, students' individual knowledge is developed and influenced by the classroom microculture including classroom activities and teaching pedagogies. Moreover, according to Cobb and Yackel's (1996) framework of emergent perspective, what becomes mathematically normative in a classroom is enabled and constrained by the students' changing mathematical beliefs and values. At the same time, these beliefs and values are themselves influenced by what is legitimized as acceptable mathematical activity. Therefore, the perspective is valuable for supporting an account of the reflexive development of student beliefs and attitudes and classroom norms in a following manner: student beliefs and attitudes towards mathematics are developed in the context of a classroom community where social norms and social mathematical

norms (Yackel & Cobb, 1996) stimulate and organize the pattern of interactions; student beliefs and attitudes towards mathematics are thus influenced by those norms; on the other hand, students and teacher, who are together forming the classroom community, negotiated on these norms; and since student beliefs and attitudes influence the interaction in the classroom community as well as make a contribution to the classroom community. Therefore, student beliefs and attitudes are important in the process of negotiating classroom norms. The above conceptual perspectives guided me to decide the types of data to collect, which are related to students' persistence and student beliefs and attitudes. The integration framework of persistence and the emergent perspectives thus will be embedded in all three groups of research questions.

Research Questions

My study will involve three sets of data. One I will call the “replicated CSPCC data”, since the data was collected by using the same instruments employed in the CSPCC study and one I will call “EAGER data” since the data was collected by using the instruments used in an NSF-funded study (under an EAGER proposal) occurring in the WVU Department of Mathematics to investigate affective traits of developmental mathematics students. I replicated this work in the context of Calculus. The third data set I will call “National data”, which are the summarized and published data drawn from CSPCC study. With these three sets of data, I would like to answer following three groups of research questions:

1a) Do different learning experiences in Calculus I influence students' attitudes and beliefs differently? 1b) Are there similarities and/or differences in students' attitudes and beliefs toward mathematics across the different versions of Calculus I offered at the local institution and 1c) how does the local data compare to the national data?

I will use the replicated CSPCC data and National Data to answer these questions. I plan to use both quantitative and qualitative analyses. Specifically, I would like to find out if there exist differences and similarities among students' attitudes and beliefs toward mathematics in the different courses and investigate the factors that affect these differences. I hypothesize that students in the different Calculus I classes will engage in their class initially with similar attitudes and beliefs, but they will diverge, perhaps significantly, after one semester of Calculus I learning experiences. I also hypothesize that our results will differ from national results.

2a) Is Calculus I students' STEM persistence predicted by students' attitudes & beliefs or perception of pedagogies? 2b) Is this relationship between persistence and students' attitudes and beliefs or perception of pedagogies moderated by the different structures of the Calculus I course?

I will use the replicated CSPCC data to answer these questions. I will examine how students think about the instructor's teaching pedagogies adopted in a classroom. This will be a mix of quantitative and qualitative analyses. Specifically, I want to investigate if students have different perceptions of teaching pedagogies in the different classes and whether these differences play a role in students' intention in STEM major. I hypothesize that students in different Calculus I classes will perceive and value various teaching pedagogies differently, especially between STEM intending and Non-STEM intending students. As a consequence, students may be impacted either positively or negatively in their attitudes and beliefs by instructor practices that will in turn affect their STEM intention. To answer this question, I will specifically compare student responses to questions about different teaching pedagogies, such as "good teaching" pedagogies and "progressive (ambitious) teaching" pedagogies (Sonnert et al.,

2015). The data will come from pre- and post-surveys given to students to examine any changes present.

3a) Are there differences in a student's level of decisiveness with which they chose their majors and their reasons for changing majors and/or careers (if applicable) across the different versions of Calculus I at the local institution? 3b) How are these differences associated with STEM persistence?

I will use the EAGER dataset to address these questions. I will explore and analyze students' reasons for leaving STEM other than by looking at their classroom-level learning experiences. Even though, the learning experience is stated as the primary reason for leaving the STEM fields/majors (as well as leaving in general), other factors also could play an important role in student decision-making. Specifically, I would like to explore students' reasons for why they choose to leave a STEM major from a point view of students' STEM-belonging, students' personality and anxiety, students' decisiveness in choosing a major, and students' self-esteem and STEM identity. I hypothesize that these factors are strongly associated with students' decisions to either leave or persist in a declared (STEM) major. To answer this question, I will analyze the data collected through the five surveys employed in the EAGER project that investigate: STEM belonging, personality, anxiety, self-esteem and STEM identity, and career decision.

Chapter 2. Methodology

Survey Instrument

The instruments for the data collection were 11 surveys. Five of them are directly borrowed from the CSPCC (section 1.3) team, and six of them are borrowed from a collection of literature. I administered the same five surveys (Appendix 1) that were used in CSPCC study: two for students (pre and post), two for instructors (pre and post), and one for course coordinators. In two student surveys, questions were asked related to students' demographics (only in pre) including academic and social backgrounds, gender, race, etc., students' attitudes and beliefs toward mathematics (both in pre and post), intention to take Calculus II (both in pre and post), and perceptions of teaching pedagogies (only in post). The other six surveys asked questions related to students' demographics, level of course anxiety, exam anxiety and study anxiety, student's sense of STEM belonging, students' situated self-esteem, and strategies for making major/career decisions.

Data Collection

The data collection consisted of three phases. The first phase was the acquisition of an IRB protocol. With the help from my advisor, an IRB protocol application for my study was submitted at the end of the spring semester of 2015. During the process of acquiring the protocol, we determined the types of information we would like to collect, including student demographics (such as gender, race/ethnicity, etc.), academic backgrounds (such as ACT score, SAT score, etc.), major, grades, academic status, and so on. The protocol was approved at beginning of the fall semester of 2015.

The second phase was to recruit participants for the study. During the construction of the consent form (part of the IRB process), we cooperated with course coordinators to overcome

several issues including the decision the dates and times for the consenting and the decision of the types of incentives offered to students. The consenting process was started in the first week of the fall semester of 2015 and ended in the second week. I consented 1051 students in person. The distribution of consented students is shown below (Table 9).

Table 9. Distribution of consented students.

Course Title	Consented Students
153	318
155 ESP/ Honors	32
155 NE	260
155 E	441
Total	1051

Table 10. Distribution of replicated CSPCC data

Course	Pre-Student	Pre-Instructor	Post-student	Post-Instructor	Coordinator
153	188	0	133	1	1
155 ESP/Honors	20	0	7	1	1
155 NE	216	2	108	6	1
155 E	311	2	366	4	1
Total	735	4	614	12 ^a	4

^a one instructor was teaching both 155 NE and 155 E, so there were actually 11 instructors who answered post survey.

The third phase was the administration of surveys. The five CSPCC surveys were constructed and distributed through the software platform “Qualtrics”. The pre-surveys for students and instructors were administrated in the first week of the Fall semester of 2015; and the post-surveys for students and instructors were administrated two weeks before the end of the semester. The survey for the course coordinators was administrated in the first week of the Fall semester of 2015. Data about survey administration and completion for each course is below (Table 10).

The surveys for students were used to collect students’ demographics, high school academic background and experiences. The main use of students’ surveys was to collect student information in regard to variables of students’ beliefs and attitudes towards mathematics, which include enjoyment, confidence, desire for more mathematics, and increased interest. The students’ survey was to collect student information in regards to variables of students’ beliefs and attitudes towards mathematic, which include enjoyment, confidence, desire for more mathematics, and increased interest. The students’ intention to continue Calculus II as well as the reasons for not continuing were also collected. Moreover, students’ perceptions of teaching pedagogies were also collected.

The surveys for instructors were used to collect instructors’ attitudes and beliefs toward teaching Calculus including teaching responsibilities, teaching philosophy, teaching instructions and their thoughts about factors influencing students’ success.

The survey for course coordinators was used to collect information about the organization of the course as well as the types of resources available to support students’ success.

Related Projects - Data Collection

At the same time when I administered the surveys for replicating the CSPCC study, I also administered seven other surveys for another project - the “EAGER project”, which is led by another research team to collect Calculus I students’ data in respects to students’ anxiety, personality traits, self-efficacy, STEM-belonging and the level of decisiveness of students and their reasons for changing majors and/or careers. I intend to use some of these data to supplement my study in a manner of explaining parts of causation. The collected data are shown below (Table 11).

Table 11. Distribution of EAGER data.

Course Title	AMARS	BFI	STEM	Situated	Career	Career
			Belonging	Self-Esteem	Post	Pre
153	181	177	154	142	127	202
155 ESP/Honors	13	12	9	6	5	14
155 NE	163	158	142	135	102	186
155 E	327	325	287	273	246	326
Total	684	672	592	556	480	728

Data Analysis

After collecting my data, I began to analyze my data by coding participants’ responses. For open questions, I coded them according to a method called “open coding” (Strauss and Corbin, 1998); following the method of “open coding”, I divided the data into smaller chunks, studied each piece, drew conclusions, and used these conclusions to develop categories. For the

Likert scale questions, I coded them with numerical values accordingly. For example, a 6-option Likert scale questions with options “Strongly Disagree” to “Strongly Agree” was coded a number ranging from 0 to 5. After coding my data, I started to analyze my data by using various statistical methods with different statistical software such as SAS, JMP and R. I analyzed data along following variables: students’ confidence, enjoyment, attitudes, beliefs, increased interest, desire to continue studying mathematics, intention to continue in the Calculus sequence, perception of instructional pedagogies, characteristics of students’ career/major decision making, reason for switching career/major decision, and whether they would earn a final grade of C or higher.

I began my analysis for the first research paper by performing exploratory statistical analysis by using t-test and ANOVA test to compare students’ responses on confidence, enjoyment, attitudes, beliefs, increased interest, desire to continue studying mathematics, intention to continue and whether they would earn a final grade of C or higher from pre-survey and post-survey, as well as to compare these local data to the national data. Afterward, in order to distinguish the impact of student experience in these courses on response data from the influence of underlying population characteristics, I compared response data related to mathematical enjoyment and confidence to student backgrounds using standardized measures of content knowledge and mathematical ability as evidenced by the mathematics portions of the SAT or the ACT, the composite scores from institutional mathematics placement test, and student high school GPA. To do this I first scaled each of these standardized proxy measures of academic preparation (SAT/ACT mathematics and local placement) to a scaled score from 0 to 100 and took the highest scale score of the three for a given student to create a new variable as an indicator of their academic preparation. Then, to mitigate the impact of the difference in the

scales of the different measures of academic preparation, I normalize this scaled placement score and the high school GPA as institutionally reported to a range from 0 to 1. Finally, I normalize the net change from the pre-survey and post-survey responses to the prompt ‘I enjoy mathematics’ and ‘I am confident in my mathematical abilities’ to the same range of 0 to 1 and compare the variation of this normalized placement score and the normalized high school GPA to the variation of the change in responses to these two questions.

After the exploratory analysis in research paper one, I move further to analyze the relationship between Calculus I students’ STEM persistence and students’ attitudes & beliefs or perception of good teaching pedagogies and perception of progressive teaching pedagogies, as well as to analyze the moderation effects of course structures these relationships in research paper two. I chose to focus good teaching and progressive teaching since these two are the main pedagogies used in Calculus I at research site, even though the CSPCC study categorized three teaching pedagogies – good teaching, progressive teaching, and teaching with technology. I considered students’ intention to continue in the Calculus sequence as the indicator of their STEM persistence, and I choose this as the dependent variable (dichotomous), and mean score of students’ attributes toward mathematics including beliefs, attitudes, confidence, enjoyment, and students’ perceptions of pedagogies as independent variables. I first centered the independent variables, it means that the average of each independent variable is 0. Then, I examined the correlation matrix among all variables. Next, I ran the following six multiple logistic regression models.

$$\text{Model A: } \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1(\text{Beliefs}) + \beta_2(\text{Confidence}) + \beta_3(\text{Attitudes}) + \beta_4(\text{Enjoyment}) + e_i$$

$$\text{Model B: } \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1(\text{Good Teaching}) + \beta_2(\text{Progressive Teaching}) + e_i$$

$$\text{Model C: } \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1(\text{Beliefs}) + \beta_2(\text{Confidence}) + \beta_3(\text{Attitudes}) + \beta_4(\text{Enjoyment}) + \beta_5(E) + \beta_6(1A) + e_i$$

$$\text{Model D: } \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1(\text{Good Teaching}) + \beta_2(\text{Progressive Teaching}) + \beta_3(E) + \beta_4(1A) + e_i$$

$$\begin{aligned} \text{Model E: } \ln\left(\frac{p_i}{1-p_i}\right) = & \beta_0 + \beta_1(\text{Beliefs}) + \beta_2(\text{Confidence}) + \beta_3(\text{Attitudes}) + \\ & \beta_4(\text{Enjoyment}) + \beta_5(E) + \beta_6(1A) + \beta_7(\text{Attitudes} * E) + \beta_8(\text{Beliefs} * E) + \\ & \beta_9(\text{Confidence} * E) + \beta_{10}(\text{Enjoyment} * E) + \beta_{11}(\text{Attitudes} * 1A) + \\ & \beta_{12}(\text{Beliefs} * 1A) + \beta_{13}(\text{Confidence} * 1A) + \beta_{14}(\text{Enjoyment} * 1A) + e_i \end{aligned}$$

$$\begin{aligned} \text{Model F: } \ln\left(\frac{p_i}{1-p_i}\right) = & \beta_0 + \beta_1(\text{Good Teaching}) + \beta_2(\text{Progressive Teaching}) + \beta_3(E) + \\ & \beta_4(1A) + \beta_5(\text{Good Teaching} * E) + \beta_6(\text{Good Teaching} * 1A) + \\ & \beta_7(\text{Progressive Teaching} * E) + \beta_8(\text{Progressive Teaching} * 1A) + e_i \end{aligned}$$

The model A is run to find the relationship between students STEM persistence and students' attributes toward mathematics. The model B is run to exam the relationship between students STEM persistence and students' perceptions of pedagogies. After running model A and model B, I created two dummy variables to represent student enrollment in 1A and E, then we run moderation analysis by considering 1A and E as two moderators, and therefore NE is considered the reference group. The model C and model D are run to examine the main effect of course structures. The model E and the model F are run to investigate whether the relationship found in the model A and B differ by course structures, meaning to find the moderation effect of course structures.

In research paper three, which is a brief descriptive report on Calculus I students' major and career exploration via a case study, I provide some focused insights to understand some parts

of the local STEM drop-out issue. I analyzed data by performing exploratory statistical analysis by running multiple simple pre- and post-survey comparisons by employing t-test and ANOVA test to compare students' responses on characteristics of students' career/major decision making and reason for switching career/major decision.

Chapter 3. Dissertation Papers

Paper 1: The effects of different versions of a gateway STEM course on student attitudes and beliefs

Abstract

Substantial research has been conducted focusing on student outcomes in mathematics courses in order to better understand the ways in which these outcomes depend on the underlying instructional methodologies found in the courses. From 2009 to 2014, the Mathematical Association of America (MAA) studied Calculus I instruction in United States (US) colleges and universities in the *Characteristics of Successful Programs of College Calculus* (CSPCC) in order to understand the impact of these courses on student experience. In this paper, we describe results from a close examination of the effect of course structure on students' attitudes and beliefs across different versions of Calculus I at a large research university in the US. We implemented a local replication of a national MAA study of calculus programs in part to identify potential relationships between various course structures and changes in attitudes and beliefs during the course. We compare our results both internally across these course structures and to the national data set. We find changes measured in confidence or enjoyment show differences across different calculus implementations but that these changes in affect do not co-vary with underlying measures of student academic backgrounds such as high school GPA. This suggests that these observed changes in attitudes and beliefs relate to the experience in our varied course structures and not to the academic characteristics of students as they enter the course. In addition to our findings, we show how this national study can be used locally to study effects of course on student affective traits.

Keywords: calculus, persistence, enjoyment, confidence

Introduction

From 2009 to 2014, a project led under the auspices of the Mathematical Association of America (MAA) investigated Calculus I instruction in United States (US) colleges and universities under the title *Characteristics of Successful Programs of College Calculus* (CSPCC). Results from this study showed that students' experiences in Calculus I have significant effects on their decisions about pursuing science, technology, engineering and/or mathematics (STEM) majors and on their attitudes toward mathematics in general (Bressoud, Carlson, Mesa & Rasmussen, 2013). Specifically, students' experiences in Calculus I are primary reasons that many are individually feeling discouraged from continuing in the calculus course sequence (Rasmussen & Ellis, 2013). Inspired by the CSPCC study and our own offering of multiple versions of this fundamental course, we conducted a study to investigate differences and similarities in Calculus I student persistence in STEM disciplines and attitudes and beliefs toward mathematics. In this paper, we seek to address the following research question: Do different learning experiences in Calculus I influence students' attitudes and beliefs differently? To answer this question, we measured attitudes and beliefs as in the CSPCC study and compared them across multiple course populations. We then isolated student academic backgrounds and compared the variability of these across the student populations with changes in these measures to determine how changes in attitudes and beliefs were related to background data in our populations.

Background

In 2012, the President's Council of Advisors on Science and Technology (PCAST) reported an historically high need for STEM graduates to strengthen the national work-force

(2012). Studies that have shown that the number of students pursuing a STEM degree has remained constant at about 30% (Carnevale, Smith & Melton, 2011; Eagan, Hurtado & Chang, 2010) while less than 40% of these students actually complete a STEM degree (PCAST, 2012). Many STEM intending students change majors (Ellis, Kelton & Rasmussen, 2014; Seymour & Hewitt, 1997) and though researchers have found many reasons for their departure (PCAST, 2012; Seymour & Hewitt, 1997), the Calculus I learning experiences of these students is consistently reported as a factor in departure (Rasmussen & Ellis, 2013; Seymour & Hewitt, 1997). Calculus I is considered by many to be a gateway through which students pursuing a STEM major must pass in order to successfully pursue their degree programs. However, the CSPCC study showed that almost a quarter of the students in any given calculus class do not achieve a passing grade (Bressoud et al., 2013). The teaching of Calculus I and its associated student persistence has received great attention in recent years, with many large-scale efforts across the US focusing on various aspects of calculus instruction and their impact on student persistence.

Much research has been done on student persistence in a number of contexts including general educational pursuits or towards the completion of coursework (Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013; Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008; Pascarella & Terenzini, 1980; Tinto, 1975, 1997, 2004). In this paper, we consider student persistence in the Calculus sequence as the act of continuing in a STEM major (Ellis, Kelton & Rasmussen, 2014; Seymour & Hewitt, 1997). According to Tinto's (1975) framework of persistence, satisfaction in the integration of social and academic life in a community has a significant impact on persistence, and later he asserted that this model also can be employed in analyzing students' learning and persistence in classrooms as communities (Tinto, 1997). He

highlights that this satisfaction is of critical importance to students during their freshman year because it is a time when their “membership in the communities of ... campus is so tenuous” (Tinto, 2004, p. 3). Most students in the US, especially those planning to major in a STEM field, take Calculus I during their first year in college. We hypothesize that the Calculus I experiences of students in various versions of the course at our institution differ significantly and have the potential to affect their attitudes toward mathematics as well as decisions about continuing to pursue a STEM major in different ways.

According to the persistence frameworks developed by Graham, et al. (2013) and Tinto (1975, 1997, 2004), attitudes and beliefs are critical requirements for STEM persistence. They argue that confidence and motivation are important factors associated with student persistence in a STEM major. Indeed, researchers have revealed that attitudes and beliefs play a very important role in student persistence (Graham, et al., 2013; Stolle- McAllister, Domingo, & Carriollo, 2011; Summers & Hrabowski, 2014). Specifically, many of these results show that non-cognitive factors such as motivation, interest, confidence, and beliefs are potentially important to STEM attrition (Burtner, 2005; Chang, Eagan, Lin, & Hurtado, 2011; Espinosa 2011; Price 2010; Schoenfeld, 1989; Seymour & Hewitt 1997). Students who succeed in mathematics display higher levels of enjoyment of, and persistence in, mathematics (Carlson, 1999) and student achievement is significantly correlated with self-confidence and expert-like mathematical beliefs (Carlson, Buskirk, & Halloun, 1999). Other research has also conclusively shown that students’ beliefs and attitudes towards mathematics are strongly correlated with achievement in mathematics classes (Pajares & Miller, 1995; Carlson, 1999; Schommer-Aikins, Duell, & Hutter, 2005). Beliefs and attitudes have been shown to have a significant impact on problem-solving behavior (Carlson & Bloom, 2005; Schoenfeld, 1992) and self-efficacy and self-confidence are

specifically strongly correlated with student success in the performance of problem solving (Pajares & Miller, 2005).

Within these frameworks of cognition, beliefs and attitudes towards the learning process and material being learned impact the process of building understanding. As such, we must examine the role students' attitudes and beliefs toward mathematics, including enjoyment and confidence, play in student success in calculus. According to Leder and Forgasz (2002), there is not a solid or common definition of 'belief' or 'attitude' since these terms "are not directly observable and have to be inferred, and because of their overlapping nature" (p.96). Other researchers hold that it is neither possible nor necessary to unify these different concepts of attitude and belief since different research problems can require different definitions (Hannula, 2012; Lewis, 2013). In this study we adopt the structure formulated by Fenneman and Sherman (1976), and the definition of attitude and belief, specifically including enjoyment and confidence, in their work. They formulated the definition of attitude(s) towards mathematics as the positive or negative emotional disposition toward mathematics, and the definition of belief(s) towards mathematics as one's psychological acceptance to the truth and value of mathematics and learning of mathematics including the usefulness, relevance and worth of mathematics in their life now and in the future. With these definitions, enjoyment refers to the degree to which students enjoy working mathematics and mathematics classes, and confidence refers to students' confidence and self-concept of their performance in mathematics. Structurally, we note that within psychological studies (Main, 2004), the notion of beliefs and values are considered precursors to attitude and that it is the latter that constitutes a predisposition to action. The definitions of Fenneman and Sherman align with this structure in the sense that a student's

beliefs about mathematics will inform their attitudes by contributing to the positive or negative emotional framework for engaging in mathematical practice.

Institutional Context

This study takes place at a large research university in the US where students can enroll in one of three different versions of Calculus I depending on their planned major and placement performance. The *non-engineering*, one-semester version (NE) serves students primarily from science related disciplines such as biology, chemistry and physics. The format of the course incorporates a highly student-focused meeting with an instructor three times per week that incorporates group learning and other activities to develop strong conceptual understanding. These activities incorporate a more active learning approach where students develop concepts through guided activities. Summative assessments focus on these concepts and avoid complex numerical processes that would require a calculator. Students meet with graduate assistants twice a week for additional work on problem solving and homework.

The *engineering*, one-semester version (E) is built around engineering-based application problems and calculus concepts are developed in the context of these problems. Three days per week students attend more traditional lecture format meetings with the instructor of record. During recitations two days per week, students work on activities led by graduate students that often align with content they are also learning in their introductory engineering courses and that maintain a high level of computational complexity. The course focuses more on technical skill development and computational precision than on deeper conceptual understanding. Many of these classes are offered on the engineering school's campus, instead of near the Department's other classes.

A third format is offered as a *two-semester Calculus I equivalent* (1A/B). Student success and placement data are used to identify a distinct cohort of students who would have previously either not been able to directly enroll in Calculus I or who are at the highest risk of failing or withdrawing from a one-semester course. Students learn the content from Calculus I over a two-semester time period allowing for more in-depth coverage of core but troublesome calculus concepts with time to review precalculus content as needed. Students meet with their instructor three times per week in a lecture format class, and once per week in a ‘laboratory’ setting with a graduate student to work on activities in groups designed to support the development of concepts.

Each version of the course has a coordinator who supervises the instructors in that course and whose philosophy about teaching and goals for the course drive their curricular decisions independent from the other courses. These courses will be referred to as versions 1A (the first half of the 1A/B sequence was the focus of our study), E and NE for the remainder of this paper.

Students’ Demographic Data

Demographic data for students in our courses for the Fall 2015 semester are shown in Table 12. A notable difference between the populations is that the NE and 1A classes have larger proportions of under-represented students. Additionally, a considerable number of students in NE take that course during their junior year, at least compared to the E and NE courses. Compared to the national sample of research universities (Bressoud et al., 2013), our students, especially those in E, are less likely to work a full-time job, and our institution has comparably fewer students from underrepresented groups.

Table 12. Student Demographics for Fall 2015 by percentages

Student Characteristic		1A <i>N</i> = 120	E <i>N</i> = 246	NE <i>N</i> = 105	National
Gender	Female	45.83	21.55	50.48	46
	Male	54.17	78.45	49.52	54
Race/Ethnicity	White	91.67	92.28	90.48	81
	Black	6.67	2.85	2.86	5
	Asian	3.33	2.85	8.57	17
	Hispanic	1.67	1.21	0.00	9.00
College year	Freshman	74.17	77.64	62.86	83
	Sophomore	14.17	19.51	20.00	10
	Junior	6.67	2.03	14.29	NA
	Senior	4.17	0.00	2.85	NA
	Others	0.83	0.81	0.00	NA
Enrolled full time					
& work >15		8.33	5.69	8.57	9
hrs/week					

Students' Academic Backgrounds

In order to characterize student ability as they enter our courses, we aggregated data from their mathematics subscore on the Scholastic Aptitude Test administered by the College Board (SAT), their mathematics subscore on the ACT exam administered by ACT, Inc. (ACT), and their high school grade point average (GPA). Students' academic backgrounds are shown in

Table 13. Overall, we conducted a pairwise comparison for average SAT/ACT (see Table 2 footnotes for descriptions) and high school grade point average with a student's t-test among the three course versions and found that 1A students' average SAT/ACT score is statistically significantly different from NE and E with p -values of 0.00059 and <0.0001 respectively, but not between NE and E. Student high school GPA is not statistically significantly different among the three versions. About half of the students in each of the E and NE versions indicate that they studied calculus in high school while a lower proportion of students in 1A did. Among our students, about one-fifth of the students in E took Advanced Placement (AP) Calculus (a Calculus course offered in high school in the US intended to prepare students for an exam which can earn them college credit) in high school and subsequently passed the AP Exam with a grade of 3 or higher, but very few in NE did so. AP scores of 3 or higher out of 5 can earn college credit at our institution.

Table 13. Students' Academic Backgrounds

Student background		1A	E	NE	National
Actual institutional average	SAT ^a	578	618	580	663
SAT/ACT mathematics Score	ACT ^a	25	28	26	29.1 ^c
High-school mathematics GPA ^b		3.62	3.65	3.64	3.77
Studied calculus in high school		35.83%	54.07%	46.67%	70%
Earned 3 or higher, AP Calculus exam		5.83%	19.51%	0.95%	26%

^a SAT is a standardized test used for college admissions in the U.S. consisting three components, and mathematics score is one of the components with a score range from 200 to 800. ACT is another standardized test used for college admissions in the U.S. consisting four components, and mathematics score is one the components with a score range from 1 to 36

^b GPA was calculated using A=4, B=3, etc. for student self-reported grades.

^c This number is calculated from the original CSPCC data set.

Compared to the national pool of research university students (Bressoud et al., 2013, Table 5, column 2), our students' average SAT/ACT raw mathematics scores and high school GPA differ significantly ($p < 0.0001$). Among all three versions at our institution, the percentage of students who took calculus in high school is much lower than the national study and the percentage of students who earned a 3 or higher on the AP Calculus exam who subsequently enrolled in a college calculus class is also substantially lower. Approximately 26% of students in the national study enrolled in Calculus I had earned a 3 or higher on the AP Calculus exam. At our institution, only 11.89% of students earned a 3 or higher. However, it should be noted that students earning a score of 4 or 5 on the AP Calculus exam can earn credit for Calculus I at our institution and would therefore normally take Calculus II without taking Calculus I. Thus, students who might increase our percentage in this category would likely have earned credit for the course already and not be enrolled in Calculus I and not in our sample.

Methods

We collected data using two surveys administered during the CSPCC study to specifically investigate student beliefs and attitudes about mathematics among the Calculus I

student population. Students received a survey between the second and third week of the fall 2015 semester and a follow up survey two weeks before the end of the semester. Extra credit for completion of the surveys was given to the participating students differently for each version as determined by the course coordinator. We surveyed a total of 1019 students, and 715 students completed either the pre- or post-survey. We report here on the 471 respondents (120 for 1A, 246 for E, 105 for NE) who completed both the pre- and post-surveys. The survey questions are mostly Likert scale questions in multiple formats (refer to Appendix A and Appendix B for details). For the 4-option Likert scale questions, the response options ranged from level “1” to level “4”, and were coded with numbers from 1- 4. For the 6-option Likert scale questions, the response options ranged from Strongly Disagree to Strongly Agree, and were coded with numbers from 0 - 5.

Table 14. Factors for analysis

Variable	Data Type/Source	Pre-survey	Post-survey
Beliefs	6-option Likert scale	X	X
	4-option Likert scale		
Attitudes	6-option Likert scale	X	X
	4-option Likert scale		
Confidence ^a	6-option Likert scale	X	X
Enjoyment ^b	6-option Likert scale	X	X
Increased interest ^c	6-option Likert scale		X
Desire to continue studying mathematics ^d	3-option Likert scale	X	X

^a “I am confident in my mathematical abilities”

^b “I enjoy doing mathematics”

^c “This course has increased my interest in taking more mathematics”

^d “If I had choice, I would never take another mathematics course/ I would continue to take mathematics”

We analyzed data along factors established in survey questions used in the CSPCC study: beliefs, attitudes, confidence, enjoyment, increased interest, and desire to continue studying more mathematics (Table 14). We run paired sample t-test and ANOVA test to compare sample means of students’ response on each factors in order to discover pre- and post-survey differences and similarities across three different instructional settings, instead of building a model relationship. Afterward, we wanted to distinguish the impact of student experience in these courses on response data from the influence of underlying population characteristics, we compared response data related to mathematical enjoyment and confidence to student backgrounds using standardized measures of content knowledge and mathematical ability as evidenced by the mathematics portions of the SAT or the ACT, the composite scores from our institutional mathematics placement test, and student high school GPA. To do this we first scaled each of these standardized proxy measures of academic preparation (SAT/ACT mathematics and local placement) to a scaled score from 0 to 100 and took the highest scale score of the three for a given student to create a new variable as an indicator of their academic preparation. Then, to mitigate the impact of the difference in the scales of the different measures of academic preparation, we normalize this scaled placement score and the high school GPA as institutionally reported to a range from 0 to 1. Finally, we normalize the net change from the pre-survey and post-survey responses to the prompt ‘I enjoy mathematics’ and ‘I am confident in my

mathematical abilities' to the same range of 0 to 1 and compare the variation of this normalized placement score and the normalized high school GPA to the variation of the change in responses to these two questions. While the Likert-type responses for the two prompts are strictly speaking of ordinal type, it is reasonable to view them as quantifying 'enjoyment' and 'confidence' for a given student and as such they can be regarded as interval or ratio variables here. In this way the normalized means show the scaled value of the populations' average state for those quantities and the normalized standard deviations give a measure of the variance of the quantity for the populations.

Results

We surveyed students' beliefs and attitudes at the beginning (pre-survey) and end (post-survey) of the semester to collect data that might reveal differences in and changes in these beliefs and attitudes during the term as well as across the course populations. For analysis, we first look at survey items that appear only on the pre-survey, then those only on the post-survey, and finally compare responses to items that appeared on both the pre- and post-survey.

Changes in Student Attributes

As stated previously, we seek to answer the research question: Do different learning experiences in Calculus I influence students' attitudes and beliefs. The pre-survey and post-survey provides identical statements specifically regarding students' attributes including attitudes, beliefs, mathematical confidence, enjoyment and desire to continue to Calculus II in order to assess any changes. We compared responses to questions that appeared on both the pre- and post-surveys (Tables 4 and 5) for their total change within each course structure cohort. For each statement (the completed statements in the full survey can be found in appendix A, questions 31, 33-37, 39), we compared its mean to examine whether there are (statistically significant) differences within each version as well as across versions in pre- and post-surveys.

We asked students about their certainty in regards to their future career by providing a statement “*How certain are you in what you intend to do after college?*”. Students in all three versions are very certain of their future career. The consistency appeared in the post-survey but was not quite as strong with a (not statistically significant) decline in each version. In the pre-survey, we saw that the differences among each version were large (Table 15, Statement 1). The differences lessened in the post-survey, but we saw no statistically significant differences across versions in either the pre-survey or post-survey.

We asked students’ view about the role of instructor by providing a statement “*The primary role of a mathematics instructor is to:*” with options range from “*work problems so students know how to do them (1)*” to “*help students learn to reason through problems on their own (4)*”. In both the pre- and post-surveys, students in all three classes have very similar views about the role of the instructor being to help students learn how to reason through problems (Table 15, Statement 2); but, in the post-survey, the level of this belief decreased in both E and NE (with a steeper decline in NE) while substantially increasing in 1A. Differences between groups grew in size, though not statistically significantly.

We asked students’ thoughts in regards unsuccessful attempts in problem solving by providing a statement “*For me, making unsuccessful attempts when solving a mathematics problem is:*” with options range from “*a natural part of solving the problem (1)*” to “*an indication of my weakness in mathematics (4)*”. Students in all three versions believe that unsuccessful attempts at mathematical problem solving are part of the learning process (Table 15, Statement 3). The pre- and post-survey responses show that this belief statistically significantly decreased in 1A, slightly increased positively in E, but remained constant in NE. In the pre-survey, we also noted that 1A had the largest percentage of the population taking

unsuccessful attempts in mathematics as indicators of weakness in mathematics in the pre-survey, but this scenario weakened markedly to the lowest in the post-survey, even though this change is not statistically significant. We do not see significant differences between NE and E between the pre- and post-surveys.

Table 15. Changes in Sample Means of Students' Beliefs and Attitudes

Statements	1A (mean)			E (mean)			NE (mean)		
	Pre	Post	<i>p</i> -value	Pre	Post	<i>p</i> -value	Pre	Post	<i>p</i> -value
1. How certain are you in what you intend to do after college?	3.14	3.05	0.46	3.09	3.06	0.69	3.20	3.09	0.36
2. The primary role of a mathematics instructor is to:	2.87	2.96	0.49	2.96	2.91	0.57	2.92	2.79	0.36
3. For me, making unsuccessful attempts when solving a mathematics problem is:	2.42	2.09	0.01	2.24	2.27	0.71	2.27	2.27	0.99
4. My score on my mathematics exam	1.92	1.97	0.72	1.93	2.47	0.00	1.92	2.48	0.00

is a measure of how

well:

5. My success in 2.53 2.68 0.25 2.64 2.75 0.20 2.64 2.59 0.68

mathematics

primarily relies on

my ability to:

6. If I had a choice, 2.61 2.67 0.63 2.98 2.67 0.00 2.52 2.35 0.24

I would (/would

not) continue taking

more mathematics

7. When studying 2.90 2.81 0.48 3.05 2.95 0.21 3.25 2.77 0.00

Calculus I in a

textbook or in

course materials, I

tend to:

We asked students' thoughts about their exam score by providing a statement "*My score on my mathematics exam is a measure of how well.*" with options range from "*I understand the covered material (1)*" to "*I can do things the way the teacher wants (4)*". Students in all versions believe exam scores measure the amount of material they understand and there was a statistically significant increase in the belief among students in E and NE that exam scores are measuring how well they can do things the way the teacher wants (Table 15, Statement 4). With pairwise

comparisons among the versions in pre- and post-surveys, we also found that there are statistically significant differences between 1A and other two versions in the post-survey (p -values < 0.001 respectively), but these differences did not appear in pre-survey. The differences between NE and E in both pre- and post-surveys are very small and not statistically significant.

We asked students' thoughts about the goal of learning calculus by providing a statement "*My success in mathematics primarily relies on my ability to:*" with options range from "*solve specific kinds of problem (1)*" to "*make connections and form logical arguments (4)*". The majority of students in all three versions tend to believe that the goal of learning calculus is to make connections and form logical arguments (Table 15, Statement 5). Students in 1A and E maintained this belief at the end of semester, but a small decline appeared in NE. In the pre-survey, we noted that 1A is quite different from NE and E with the least number of students holding this belief but there is not a difference between NE and E. Results of the post-survey revealed a different picture. The big differences between 1A and other two versions decreased while the difference between NE and E became larger, though neither was statistically significant.

We asked students' desire for more mathematics by providing a statement "*If I had a choice*" with options range from "*I would never take another mathematics (1)*" to "*I would continue to take mathematics (4)*". Students in all versions indicated a low desire to continue studying mathematics (Table 15, Statement 6) unless required to do so both at the beginning and the end of semester, and we observed a decline in all versions with an especially steep decline in E that was statistically significant and a large decline in NE (not statistically significant). The differences between 1A and E and between NE and E were statistically significantly large in the pre-survey (p -values < 0.001 respectively), but very small between 1A and NE. Results from the

post-survey revealed a different picture. The differences between 1A and NE became statistically significantly large (p -value = 0.0276), but the difference between 1A and E diminished. The difference between NE and E is still statistically significant (p -value = 0.0123), but the gap is much smaller.

We asked students' views about how to study materials by providing a statement "*When studying Calculus I in a textbook or in course materials, I tend to:*" with options range from "*memorize it the way it is presented (1)*" to "*make sense of the material so I understand it (4)*". The data also revealed that a large number of students in all three versions tend to understand that trying to make sense of the materials is a better method of studying Calculus I instead of trying to memorize them (Table 15, Statement 7). However, a pre- and post-survey comparison indicated a decrease in this tendency, especially in NE where there was a statistically significant massive shift. In the pre-survey, we saw that large differences occurred among the versions, and differences between NE and other two versions were statistically significant (p -values <0.001 respectively). In the post-survey, the big differences still there, but not statistically significant anymore.

Students were also asked about their confidence, enjoyment in mathematics and desire for more mathematics (Table 16). Students across versions reported high levels of confidence and enjoyment of mathematics, even though they are all unexpectedly at statistically significant lower levels (p -values <0.0001) than the national pool (Bressoud et al., 2013, Table 7, column 2). Also, overall students reported a statistically significant decrease in these three attributes with p -values <0.01 from pre-survey to post-survey. This trend is consistent with the national data (Bressoud et al., 2013, Table 9, column 3).

There were also differences among students across the three versions by specifically examining confidence, enjoyment and desire to continue in mathematics in each version with a pre- and post-survey comparison. A deeper investigation showed that students in 1A have statistically significantly lower levels of confidence and enjoyment with p -value < 0.05 comparing to NE and E; furthermore, between E and NE, students in E have a higher level of

Table 16. Change in Students' Confidence, Enjoyment and Desire for More Mathematics

Variables		1A		E		NE		National
		Mean	p-value	Mean	p-value	Mean	p-value	Mean
		(SD)	(ES)	(SD)	(ES)	(SD)	(ES)	(SD)
Confidence	Pre	3.57	0.46	3.84	<0.01 (-	3.80	<0.01	4.93
		(0.97)	(-0.10)	(1.09)	0.70)	(1.13)	(-0.67)	(1.01)
	Post	3.47		3.08		3.04		4.40
		(1.13)		(1.23)		(1.41)		(1.19)
Enjoyment	Pre	3.31	0.76	3.73	<0.01 (-	3.24	0.01	4.69
		(1.36)	(-0.04)	(1.16)	0.52)	(1.51)	(-0.33)	(1.24)
	Post	3.26		3.13		2.74		4.28
		(1.41)		(1.28)		(1.58)		(1.35)
Desire for more math	Pre	2.61	0.63	2.98	0.01	2.52	0.24	2.97
		(1.07)	(-0.06)	(0.94)	(-0.33)	(1.11)	(-0.15)	(1.00)
	Post	2.67		2.67		2.35		2.83
		(1.11)		(1.10)		(1.09)		(1.07)

confidence, and enjoyment than those in NE, and the difference in enjoyment is statistically significant with a p -value <0.001 . There is a small decrease in confidence and enjoyment but a small increase in desire for more mathematics in 1A, but these changes are not statistically significant. On the other hand, we observed dramatic decreases in students' confidence and enjoyment in E & NE, and t-tests show that these shifts are statistically significant. Moreover, we see a statistically significant decrease in students' desire to continue in mathematics in E, but not in NE. In addition, the negative effects on these three attributes in E are much greater than in NE. Therefore, students' beliefs and attitudes towards mathematics in 1A kept steady. The overall declines in student's attitudes and beliefs are most affected by the declines in E and NE.

The Effects of Different Course Learning Experiences

Ultimately, we seek to determine whether the observed changes in students' attitudes and beliefs are related to the students' learning experiences in each version of our course. As the beginning step in this process we first attempt to distinguish the patterns found in the underlying students' background characteristics from the patterns of enjoyment, confidence and their observed changes. For this analysis we consider placement data derived from SAT/ACT mathematics subscores and high school GPA as indicators of demographic variability. We then then normalize the values for these scores, the Likert scale responses for enjoyment and confidence, and then their observed changes by dividing by the range of each of these scores to arrive at values that vary from 0 to 1. The observed normalized means and standard deviations are recorded in Table 17. We then observe that the overall variability for both enjoyment and confidence, as measured by the standard deviation of the distributions, is roughly two to three

times as large as the variability of our demographic measures, and larger than the variability found in the change measured from the pre- to post-survey for both variables.

Table 17. Normalized Descriptive for Confidence, Enjoyment and Background

	1A		E		NE	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Standardized Placement	0.71	0.08	0.77	0.12	0.73	0.17
High School GPA	0.73	0.13	0.76	0.12	0.75	0.17
Pre Enjoyment	0.65	0.28	0.74	0.24	0.64	0.31
Pre Confidence	0.71	0.20	0.76	0.23	0.76	0.23
Post Enjoyment	0.65	0.29	0.62	0.26	0.55	0.32
Post Confidence	0.69	0.23	0.61	0.25	0.60	0.29
Enjoyment Change	0.50	0.13	0.44	0.13	0.45	0.15
Confidence Change	0.50	0.11	0.43	0.13	0.42	0.16

Next, we seek to determine if any of the measured variances in the values for enjoyment and confidence or the variances of the changes of these values matches the variance found in the underlying demographic variables in our populations. The correlations for the enjoyment and confidence indices with the normalized SAT/ACT mathematics placement data and the normalized high school GPA (Table 18) show that in one case, correlation with high school GPA for NE, we see statistical significance with the pre-survey confidence levels. All other correlation

levels are low and not significant. We also find that placement correlates with both confidence and enjoyment in the post-survey data for 1A and E, but less so for NE.

Table 18. Correlation of Enjoyment and Confidence with Content Background Demographics

	1AB		E		NE	
	Correlation	Correlation	Correlation	Correlation	Correlation	Correlation
	with	with High	with	with High	with	with High
	Placement	School	Placement	School	Placement	School
		GPA		GPA		GPA
Pre Enjoyment	-0.063	0.042	0.001	-0.031	-0.100	-0.184
Pre Confidence	-0.121	0.071	-0.014	0.061	-0.054	-0.219*
Post Enjoyment	0.339**	0.182*	0.197**	0.035	0.228*	0.222*
Post Confidence	0.237**	0.010	0.169**	0.072	0.174	0.071
Enjoyment Change	0.178	0.046	0.156*	0.035	0.076	-0.105
Confidence Change	0.182*	0.225*	0.167**	0.095	0.121	-0.069

** Significant at the p -value < 0.01 level (two-tailed). *significant at the p -value < 0.05 level (two-tailed)

Finally, we form the null hypothesis H_0 that the variance of the demographic variables represented by normalized placement data derived from SAT/ACT mathematics subscores, σ_{SP} , and high school GPA, σ_{HS} , are the same as the variances for the change in enjoyment and the change in confidence, σ_{CE} and σ_{CC} observed. We then check to see if one of the four pairings, σ_{SP}

$= \sigma_{CE}$, $\sigma_{HS} = \sigma_{CE}$, $\sigma_{SP} = \sigma_{CC}$, and $\sigma_{HS} = \sigma_{CC}$, is true. Wilcox (2016) and Morgan (1939) equate this to showing that two random variables X and Y will have the same variance if the Pearson correlation of the variables $U = X - Y$ and $V = X + Y$ vanishes. That is

$$Var(X) = Var(Y) \Leftrightarrow Cov(X - Y, X + Y) = 0$$

Computing the correlations for the sum and difference pairs of the change in enjoyment and change in confidence with either placement or HSGPA in our case we find that none of the changes co-vary with the underlying demographic variables since the covariance vanishes. This implies that impact of student background can be distinguished from the impact of the different course experiences on student enjoyment and confidence. This result in turn suggests that student experience is a stronger driver than background for the changes observed and given the different levels of the change for each version as shown above, this is strong evidence that the different course experiences have different impacts on student enjoyment and confidence.

Discussion

As noted earlier in this work, research has consistently indicated that the affective aspects of student non-cognitive factors such as attitudes, beliefs, confidence, enjoyment, desires and other underlying beliefs, have an impact on STEM persistence (Burtner, 2005; Chang, Eagan, Lin, & Hurtado, 2011; Espinosa, 2011; Price, 2010; Seymour & Hewitt, 1997; Schoenfeld, 1989). In the current work, we observe in the 1A format small decreases in confidence and enjoyment and a small increase in desire for more mathematics that were not significant. Students in NE also showed a decrease in desire for more mathematics but this change was not statistically significant. The levels of these responses were not as high as was observed in the national study, and students in 1A demonstrated lower levels of agreement in confidence, enjoyment, and desire for more mathematics compared to the E and NE populations.

Our main result shows that after engaging in the E course structure students stated a larger, statistically significant decrease in confidence, enjoyment and desire to continue in mathematics and in the NE course structure they showed similarly high statistically significant decreases in confidence and enjoyment when compared to the national population. The strong difference in the response of the 1A group compared to the other two suggests that this population has different levels of enjoyment in mathematics and confidence in their mathematical abilities from the larger aggregated local calculus NE and E populations as well as from the national one-semester calculus population.

Data for E began with confidence and enjoyment levels a point lower than the national results and the effect size we observe in the two variables, ranging from -0.33 to -0.70, are all larger than observed nationally. Students in NE also began with lower levels, but the effect sizes were similar to the national population. Interestingly, students in E exhibit similar levels of desire to continue as the national cohort, but the decrease in that desire is more than twice the size as that observed nationally. Students in the other two course structures enter with lower desire to continue, but their desire remains more constant; NE population's decreases with an effect size of -0.153 while the 1A population's actually increased. It is reasonable to conclude that our population of students is in some way different enough from that of the national study and that an accurate determination of these differences might shed light on what aspects of our course structures resonate with our populations and which do not.

These distinctions seen from the point of view of the different course structures then suggest a similar comparison with outcomes in student behaviors. Viewed from the point of view of retention, Tinto (1975) has identified a number of areas that impact student persistence in their educational track. These can in part be characterized as either facet of academic or of social

integration. Examples of academic integration (Tinto, 2004; Elkins, Braxton, & James, 2000) include grade outcomes, a student's value of the learning process and what they learn, their enjoyment of a subject, their enjoyment or appreciation of the learning process, the level to which they identify with existing academic norms and the level to which they identify with the role of 'student'. In addition, student attitudes and beliefs impact their enjoyment and are related to their confidence in their abilities (Wesson & Derrer-Rendall, 2011). In the data from this study, response rates to the three items concerning confidence and enjoyment show differences across course structures for 'I understand the mathematics that I have studied', 'I am confident in my mathematical abilities' and 'I enjoy doing mathematics'. Of these, the question regarding confidence shows that 7% more of the students in E respond as confident than in NE and 13% more than 1A. We expect then, higher persistence of enjoyment and other beliefs for this group compared to others. Surprisingly, we see much higher negative effect sizes for E than for either NE or 1A on enjoyment, confidence and desire for more mathematics coursework.

On the other hand, thinking of self-efficacy as our perception of our ability to deal with a situation (Pajares & Miller, 1995; Ormrod, 2006), attitudes and the underlying beliefs that support them tend to move towards negative or unsupportive actions when our self-efficacy is lower and so we would expect students with lower indicators of self-efficacy to exhibit larger negative changes in beliefs. That is, if we perceive ourselves as being incapable of impacting a situation such as an outcome on a mathematics exam, we tend to move away from attitudes or beliefs that support positive action. With this in mind, we can look for this within our data and outcomes and we find that, indeed, the higher negative effect size for E suggests some underlying issue with self-efficacy interacting with the course structure. Students in that course structure exhibit higher levels of self-efficacy and confidence, as expected, but these beliefs are

less robust during that course than those of others again implying that indeed, the course structure itself has an impact on the students that was negative regardless of their academic background on entering it.

Our current findings focus on how student beliefs and attitudes change based on their experiences in our courses. A natural extension will be to analyze whether and how students experienced their Calculus I courses differently and to attempt to align that with the more granular differences in instruction in the three formats. In addition, it is unclear whether and how the data can be used to actually implement instructional change in the courses. The data do, however, encourage us to further investigate the reasons for explaining how these differences occurred. Looking specifically at subsets of these populations such as only STEM intending, gender subgroups, or STEM persisting subgroups, may yield insights into what aspects of these courses are effective. At very least, we hope to provide baseline data needed to document and analyze change in these factors as the courses pursue interventions to retain talented STEM majors.

Our findings represent an important first step in understanding the way in which the national results of the CSPCC study can be used to understand the effects of a local implementation of calculus with a large population involving varied goals and backgrounds. For both the external comparison to the national data and internal comparisons within the three versions of the course offered at our institution, the small size does raise questions about the robustness of our data; if the sample size for the 1A and NE were much larger, the comparisons could be much more convincing. However, at a minimum, these findings highlight several other questions for future work: whether students do indeed benefit more long-term by taking the two-semester slow-paced calculus and whether it is better to group STEM-intending and non-STEM-

intending students for this coursework. This work also provides a basis for making informed decisions about changes in courses, specifically in E to address the significant decrease in confidence, enjoyment and desire to continue in mathematics.

Conclusion

In this report we compare students' beliefs and attitudes toward mathematics across three different offerings of Calculus I at a single institution, and a number of differences were observed in student responses to the courses. We draw the following conclusions from this study as described below.

On the whole, prior to taking Calculus I at our institution, our students had academic backgrounds that suggested that they would be successful in our courses, high levels of confidence, beliefs, enjoyment and desire for more mathematics, even though the levels of these responses were not as high as those observed in the national study. Also, students in the 1A 'stretch calculus' demonstrated lower levels of agreement in these areas compared to the E and NE populations.

Focusing more on specific student beliefs and attitudes, we found a dominant belief in the role of the instructor, the process of problem solving, and the goal of learning calculus across all three versions. These outcomes are again similar to those from the national study. In this work, however, we are more interested in any observed contrasts since our research questions focus on the differences in student's beliefs and attitudes towards mathematics among students in the different versions of the course. As noted above, students in 1A have a higher level of beliefs, enjoyment and desire for more mathematics but a lower level of confidence, while in contrast students in E and NE possess greater self-confidence (Table 15 & Table 16).

In conclusion, to answer our research question, results indicate that student experiences in three versions of Calculus I at our institution have an effect on both their beliefs and attitudes

toward mathematics. Moreover, the impact of the course structures is different, and we were able to isolate the impacts within course structures from the student demographic backgrounds within those structures, implying that some aspects of the course experiences themselves are responsible for these differences. We hypothesize that the strongly traditional lecture-based format of the E course led to a stronger negative impact on students' confidence and enjoyment in mathematics though there may be other properties of the structure responsible for this effect. Further work needs to be done to determine what role the way in which engineering majors are concentrated in E and other science majors in NE might be responsible for some of these differences, but our analysis indicates that the changes observed in attitudes and beliefs are independent of a student's content background and preparation.

Paper 2: The moderation effect of course structures on the relationship between persistence and students' attitudes and beliefs or perceptions of pedagogies

Abstract

Student persistence in science, technology, engineer, and mathematics (STEM) field has been one of important focus in mathematics education research. A constant rate of STEM student enrollment coupled with a high drop-out rate has been a striking issue. Many studies have been dedicated to investigate the influence factors that have played a role on this problem; and the factor that has been cited most is the learning experience in an introductory mathematics course – Calculus I. One of the research results has indicated that there is a great relationship between STEM persistence and student attributes or student perceptions of pedagogy. In this paper, we investigated the impact of three different Calculus I course settings on the relationship. Our finding showed that course structures are statistically significant important in the relationship.

Keywords: Calculus, Persistence, Attitudes, Perceptions of Pedagogies

Introduction

A constant enrollment rate with a high drop-out rate in science, technology, engineering, and mathematics (STEM) field has been a striking issue in mathematics education research. Much research has been devoted to solve this problem by finding and investigating the impacting factors in support of improving the STEM persistence. Led under the auspices of the Mathematical Association of America (MAA), a national scale study under the title *Characteristics of Successful Programs of College Calculus* (CSPCC) was conducted to investigate Calculus I instruction in U.S colleges and universities. One of the goals of this study was to examine the impact of students learning experiences in Calculus I on students' persistence

on pursuing a STEM major and on students' attitudes and beliefs. This national research studied Calculus I students' learning experiences focusing on the effect of their attitudes and beliefs and perceptions of teachers' pedagogy on their STEM persistence. There are two major results from this work. One result showed that a student's STEM intention is affected by their perception of instructors' instructional methodologies (Bressoud, Carlson, Mesa & Rasmussen, 2013). Another result showed that students' attitudes and beliefs toward mathematics are correlated strongly with their perception of instructors' pedagogical approach (Sonnert, Sadler, Sadler & Bressoud, 2015). Therefore, this national study evidently showed that student experiences in Calculus I are a primary factor impacting a student's decision whether to continue in the calculus course sequence (Rasmussen & Ellis, 2013). Inspired by the CSPCC study and our own offering of multiple versions of this fundamental course, we conducted a study to investigate relationships between Calculus I students' STEM persistence and students' attitudes and beliefs and perception of pedagogies in three different instructional settings. In this paper, we seek to address the following two research questions:

- **RQ1:** Is Calculus I students' STEM persistence predicted by students' attitudes & beliefs or perception of pedagogies?
- **RQ2:** Is the relationship between persistence and students' attitudes and beliefs or perception of pedagogies moderated by the different structures of the Calculus I course?

Literature Review

The National Science Foundation (2014) has reported that the number of jobs requiring STEM skills are projected to increase by 8.7 percent in the U.S job market. As reported by Giffi, et al. (2015) and Morrison et al. (2011), there is a shortage in the supply of STEM graduates to fill 600,000 STEM related positions in manufacturing sectors and this shortage is likely to

increase to two million over the next decade if there is no further intervention. In a recent report, the President's Council of Advisors on Science and Technology (PCAST, 2012) reported that the national work-force needs a tremendous number of STEM graduates to support its competitive position in the global market. Yet, studies related to STEM retention have shown that despite this substantial demand, the number of STEM intending students remains confoundingly low (Chen & Soldner, 2013). According to Seymour and Hewitt (1997), there is a 40 percent drop-out rate for engineering students, a 50 percent drop-out rate for physical and biological sciences students, and a 60 percent drop-out rate for students in mathematics coursework. Many other studies also have shown that the number of STEM intending college students has maintained a constant rate of 30% and that less than 40% of them actually complete a STEM major (Carnevale, Smith & Melton, 2011; Eagan, Hurtado & Chang, 2010). Tai et al. (2006) showed that the number of graduates in science programs has declined significantly, despite the fact that STEM programs are considered to be very desirable and meaningful career paths by many STEM entrants. According to Chen and Soldner (2013), the least popular science program is the physical sciences, attracting approximately 3 percent of STEM entrants. In addition, Sunstein (2013) found that academic performance and overall college success of the U.S students are lower for STEM graduates compared to those in Australia, China, England, Japan, and Russian.

To better understand the nature of this contradictory situation, there has been a long-sustained effort to study students' STEM persistence in mathematics educational research (Seymour & Hewitt, 1997; Tinto, 2004; Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013). According to the persistence frameworks developed by Graham, et al. (2013) and Tinto (1975, 1997, 2004), satisfactory integration into the social and academic life of a community has a significant impact on persistence, and later Tinto asserted that this model also

can be employed in analyzing students' learning and persistence in classrooms as communities (Tinto, 2004). In these persistence frameworks, the effectiveness of instructors' teaching plays a critical role in affecting a student's decision about whether to dropout. Many large-scale national research projects also have focused on studying the factors affecting the retention rate of STEM candidates such as the previously mentioned *Characteristics of Successful Programs of College Calculus* (CSPCC, 2009-2014). The results of these projects showed that the most significant factor impacting STEM persistence is students' perception of instructional pedagogies (Ellis, Kelton, & Rasmussen, 2014; Bressoud et al., 2013). Seymour and Hewitt (1997) categorized and ranked the reasons that students indicated for switching out of STEM majors related to learning experiences, and unsatisfactory experience with poor teaching is ranked the highest. The results showed that 90% of students who switch out said they switched out because of a concern about the poor quality of teaching including the absence of faculty-student interaction, lack of preparation and organization on the part of the instructor and dryness of presentations. The CSPCC studies identified two collective categories of teaching pedagogies, "Good Teaching" (GT) and "Progressive Teaching" (PT) (Bressoud et al., 2013; Sonnert et al., 2015). They observed that STEM intending students and Non-STEM intending students had different perceptions on these two types of instructional methodologies. They also observed that these two methodologies together can significantly lower the switch rate and improve the students' outcome, and in general "good teaching" is more important than progressive teaching. According to several prior studies (Rogers & Ford, 1997; Seymour & Hewitt, 1997; Cheryan, Master, and Meltzoff, 2015), students lose their interest in STEM programs because of several unpleasant experiences in science courses, and the poor teaching techniques of some instructors is cited the most. A notable number of switchers also experienced an un-supportive learning environment

where instructors are hard to approach with an unwillingness to provide assistance on learning and give a weed-out talk at the very beginning of the course (Seymour & Hewitt, 1997; Hunter, Thiry, Holland, Harer, & Seymour, 2016). Both switchers and persisters specifically criticized the instructor's pedagogical techniques of teaching. The most common ones are poor preparation of the lecture, a lack of sequencing or coherence on material, and little attempt at checking students' understanding (Seymour & Hewitt, 1997; Hunter, Thiry, Holland, Harer, & Seymour, 2016). Ellis, Kelton, and Rasmussen (2014) specifically analyzed the difference between students' and instructors' perception of instructors' pedagogical activities in teaching Calculus I, and concluded that the instructor's pedagogy is the main factor impacting students' persistence in Calculus I. Students indicated that instructors did not display an understanding of the relationship between the amount of material to teach/learn and the constraint of time allotted to do so.

Other critical requirements for STEM persistence in the persistence frameworks developed by Graham, et al. (2013) and Tinto (1975, 1997, 2004) are students' attitudes and beliefs. They claimed that confidence and motivation are significant factors in predicting student persistence in a STEM major. Indeed, researchers have revealed that student persistence are strongly associated with students' attitudes and beliefs (Graham, et al., 2013; Stolle- McAllister, Domingo, & Carriollo, 2011; Summers & Hrabowski, 2014). Many of these results explicitly identified the importance of non-cognitive factors such as motivation, interest, confidence, and beliefs in explaining STEM attrition (Burtner, 2005; Chang, Eagan, Lin, & Hurtado, 2011; Espinosa 2011; Price 2010; Schoenfeld, 1989; Seymour & Hewitt 1997). Carlson (1999) found that students carried a high level of enjoyment of mathematics when they succeed in mathematics, in turn attracting them to persist in mathematics. Carlson, Buskirt, and Halloun

(1999) also claimed that self-confidence and expert-like mathematical beliefs are essential aspects in understanding a student's achievement in mathematics. Other research has also conclusively shown that students' beliefs and attitudes towards mathematics are strongly correlated with achievement in mathematics classes (Pajares & Miller, 1995; Carlson, 1999; Schommer-Aikins, Duell, & Hutter, 2005). Beliefs and attitudes have been shown to have a significant impact on problem-solving behavior (Carlson & Bloom, 2005; Schoenfeld, 1992) and self-efficacy and self-confidence are specifically strongly correlated with student success in the performance of problem solving (Pajares & Miller, 1995). Mattern, Radunzel, and Westrick (2015) found that the analytical and mathematical skills that do not meet the needs of their coursework are major contributing factors to STEM attrition. As reported by Noel-Levitz (2013), 45 percent of incoming freshmen had significant problems with mathematics. We, as STEM education researchers, understand that mathematics is central to competencies in STEM programs, and analytical and mathematical skills are very critical to success in STEM programs. Calculus I is the first course that most STEM intending students take, and this course is considered as a gateway course for most STEM majors. Studying students' learning experience in this course is essential. According to the report from the national-scale study of CSPCC, almost a quarter of the students in any given calculus class do not achieve a passing grade (Bressoud et al., 2013). Research also found that the Calculus I learning experience is consistently reported as a factor in departure (PCAST, 2012; Rasmussen & Ellis, 2013; Mattern, Radunzel, & Westrick, 2015; Ellis, Fosdick, & Rasmussen, 2015; Seymour & Hewitt, 1997). Therefore, the improvement of the instruction of Calculus I in an effort to keep and increase the number of STEM intending students has received a great attention in recent years. The results of our study contribute by providing a richer picture of successful college calculus teaching

programs and a better understanding of calculus offerings and the aspects of the different programs that are and will be most successful.

The CSPPC and other prior studies found that there are relationships between students' STEM persistence and students' attitudes and beliefs or perceptions of pedagogies in general. However, these studies have not taken characteristics of course structures into consideration. The purpose of our study is to replicate the CSPCC study and first to examine effects of student attitudes and perceptions of pedagogy on persistence and second to investigate the effects of course structure in these relationships. Thus, we sought to answer two research questions: (a) Is Calculus I students' STEM persistence predicted by students' attitudes & beliefs or perception of pedagogies? (b) Is this relationship between persistence and students' attitudes and beliefs or perception of pedagogies moderated by the different structures of the Calculus I course?

Methods

This study takes place at a large research university in the U.S where students can enroll in one of three different versions of Calculus I depending on their planned major and placement performance. The survey instruments from the CSPCC study were obtained and student cohorts identified in three calculus variants offered at a larger research university in the US.

The first one is called *non-engineering* (NE). This is the traditional Calculus I course for non-engineering majors. The length of this version is one-semester. Students in this version are primarily from science related disciplines such as biology, chemistry and physics. In this format, students meet with an instructor three times per week participating in group learning and other activities to develop strong conceptual understanding. Instructors deliver these activities with a more active learning approach to help students developing concepts through guided activities. Comprehensive assessments focus on these concepts and avoid complex numerical processes

that would require a calculator. In addition, students are required to attend recitations led by a graduate assistant twice a week for additional work on problem solving and homework. Both the class and recitation are capped at 34 students, some sections smaller.

The second one is called *engineering* (E). This course is one-semester. It is built around engineering-based application problems and calculus concepts are developed in the context of these problems. Students in this version major on an engineering discipline. Students meet with an instructor three days per week. Instructors teach materials with a more traditional lecture format. During recitations two days per week students work on activities led by graduate students that often align with content they are also learning in their introductory engineering courses and that maintain a high level of computational complexity. The class and recitations are capped at 40 students; some sections are smaller. The course not only focuses on conceptual understanding, but also focuses on technical skill development and computational precision. Many of these classes are offered on the engineering school's campus, instead of near the Department's other classes.

A third format is the *two-semester Calculus I equivalent* (1A/B). Student success and placement data are used to identify a distinct cohort of students who would have previously either not been able to directly enroll in Calculus I or who are at the highest risk of failing or withdrawing from a one-semester course. The length of this format is two semesters. It gives students an opportunity to learn the content from Calculus I at a slower pace, allowing for more in-depth coverage of core but troublesome calculus concepts with time to review precalculus content as needed. Students meet with their instructor three times per week in a lecture format class, and once per week in a 'laboratory' setting with a graduate student to work on activities in

groups designed to support the development of concepts. The class and labs are capped at 80 students, some are smaller, but some are larger.

There is a coordinator for each version of the course. The coordinator supervises the instructors in that course and his/her philosophy about teaching and goals for the course drive the curricular decisions independent from the other courses. There is a common course syllabus in each of the three formats. However, instructors in the *non-engineering* course are allowed to modify the home-work grading policy. These courses will be referred to as versions 1A (the first half of the 1A/B sequence was the focus of our study), E and NE for the remainder of this paper.

Procedure

The data were collected using a survey that had been used in the CSPCC study (CSPCC, 2009-2014). Before the data collection, an IRB approval was obtained. Afterward, we administrated the survey at the end of the fall 2015 semester (i.e., two weeks before final exam). Extra credit for completing the survey was given to the participating students differently for each version as determined by the course coordinator. We surveyed a total of 1019 students and 614 students completed the corresponding survey.

Participants

We restricted our data to only those with complete data, which means students completed all fields in the survey. We report here on the 396 student respondents. The demographic information is shown in Table 19 below. Chi-Square test shows that E has statistically significant more males and more STEM intending students than other two versions.

Table 19. Demographics of participants

	E	NE	1A	Total

Number of students		206 (52.02%) ¹	89 (22.47%) ¹	101 (25.51%) ¹	396
Gender	Female ²	44 (21.55%)	45 (50.48%)	46 (45.83%)	135
	Male ²	162 (78.45%)	44 (49.52%)	55 (54.17%)	261
Ethnicity	White ²	190 (92.23%)	81 (91.01%)	92 (91.09%)	363
	Black ²	6 (2.92%)	3 (3.37%)	7 (6.93%)	16
	Other ²	10 (4.85%)	5 (5.62%)	2 (1.98%)	17
Intention to take Calculus II	STEM	193 (93.69%)	48 (53.93%)	73 (72.28%)	314
	Intending ²				
	Non-STEM	13 (6.31%)	41 (46.07%)	28 (27.72%)	82
	Intending ²				

¹ the percentage number is calculated in respect to total sample size. ² the percentage number is calculated in respect to sample size of each version

Measures

We collected survey data from students in three types of Calculus I courses. Students were asked about their beliefs and attitudes about mathematics, STEM intention, and perceptions of their instructor' teaching pedagogies among the Calculus I student population. There are sixteen (16) questions asking about beliefs and attitudes toward mathematics (CSPCC, 2009-2014). Among these sixteen questions, nine (9) questions ask about beliefs, e.g. *“Mathematics is about getting exact answers to specific problems”*; three (3) questions ask about attitudes, e.g. *“When studying Calculus I in a textbook or course materials, I tend to memorize it the way it was presented/make the sense of the material so I understand it”*; three (3) questions ask about

confidence, e.g. *“I am confident in my mathematical ability”*. Questions in each of three categories are a mixture of 4-option Likert scale questions with level of “1” to “4” and 6-option Likert scale questions with options “Strongly Disagree” to “Strongly Agree”. Further, each of these three categories was checked for its reliability with a Cronbach’s Alpha greater than 0.89. In addition, there is one (1) 6-option Likert scale question ask about enjoyment, *“I enjoy doing mathematics”*, with options “Strongly Disagree” to “Strongly Agree”. We checked the normality of responses for this question, and it is a little bit skewed to the left of normal distribution.

There are total thirty-three (33) questions asking about perceptions of teaching pedagogies, consisting twenty-one (21) questions about Good Teaching pedagogies (GT), e.g. *“During class time, how frequently did your instructor: show how to work specific problems?”*, and twelve (12) questions about Progressive Teaching pedagogies (PT.), e.g. *“During class time, how frequently did your instructor: have students work with one another?”*. Each of these questions were 6-option Likert scale question either with options of “Strongly Disagree” to “Strongly Agree”, or with options of “Not at all -1” to “Very often -6”.

In addition, there is a question asking students “Do you intend to take Calculus II?” with options of “Yes”, “No”, and “Not sure”. This question is used to determine the students’ persistence. STEM intending students’ intention to continue taking Calculus II has been considered a good indicator for determining STEM persistence in the literature (Ellis, Kelton, and Rasmussen, 2014). Therefore, students who responded “Yes” are considered as persisters, and who responded “No” are considered as switchers. We excluded the students who provided a “Not sure” response because of a very small number ($n = 13$).

Plan for Analysis

We chose students STEM persistence as our dependent variable (dichotomous), and mean score of students’ attributes toward mathematics including beliefs, confidence, attitudes,

enjoyment, and students' perceptions of pedagogies including good teaching and progressive teaching as independent variables, and we denoted these independent variables as $x_1, x_2, x_3, x_4, x_5, x_6$ respectively. We first centered our independent variables. Thus, the average of each independent variable is 0. First, we examined the correlation matrix among all variables. Next, we ran six multiple logistic regression models to answer RQ1 and RQ2.

The first two of six models are used to answer RQ1. The first model tests the relationship between students STEM persistence and students' attributes toward mathematics. The second model tests the relationship between students STEM persistence and students' perceptions of pedagogies.

To answer RQ2, first we created two dummy variables to represent student enrollment in 1A and E with NE as the reference group. Then we ran a moderation analysis by considering 1A and E as two moderators. The third and fourth model examined the main effect of course structures. The fifth and sixth models investigate whether the relationship found in the first and second model differ by course structures. The results of fifth and sixth models together will answer RQ2.

Results

Analysis results for RQ1

We ran a correlation analysis among our dependent and independent variables, and the results are reported in Table 20. All the correlation coefficients are considered to be small or very small, and they are all statistically significant with a p -value less than 0.01.

Table 20. Correlation matrix of variables

	1	2	3	4	5	6	7

Persistence	1.00						
Beliefs	0.12	1.00					
Confidence	0.15	0.59	1.00				
Attitudes	0.21	0.33	0.36	1.00			
Enjoyment	0.23	0.47	0.64	0.49	1.00		
Good Teaching	0.05	0.33	0.41	0.26	0.31	1.00	
Progressive Teaching	-0.07	0.17	0.13	0.08	0.06	0.55	1.00

To answer of RQ1, we ran the following model to study the relationship between student persistence (as dependent variable) and student beliefs (x_1), confidence (x_2), attitudes (x_3), and enjoyment (x_4) (as independent variables).

$$\text{Model A: } \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + e_i$$

The results of model A are reported in Table 21. The results show that students' attitudes and

Table 21. Students persistence predicted by students' attitudes and beliefs

Predictor	Coefficients	<i>SE</i>	Odds Ratio	ρ -value
Intercept	1.53	0.15	0.82	<0.01
Beliefs	0.14	0.36	0.54	0.70
Confidence	0.12	0.17	0.53	0.45
Attitudes	0.69	0.24	0.67	<0.01
Enjoyment	0.29	0.12	0.57	0.02

enjoyment are statistically significant positively predicting students' persistence. As a student's level of attitudes and enjoyment increases, students are more likely to persist. At average level of attitudes and enjoyment, a student's probability to persist is 82%. Specifically, as shown in Figure 2, for one standard deviation (SD) increase in level of attitude, the probability of persistence increases about 6%; for one standard deviation increase in level of enjoyment, the probability of persistence increases about 5%.

Figure 2. Comparison on the relationship of attitudes and persistence at different level; and comparison on the relationship of enjoyment and persistence at different level

Notes. Predicted values for low attitudes are 1 SD ($SD = 0.62$) below the mean and high attitudes are 1 SD ($SD = 0.62$) above the mean; Predicted values for low enjoyment are 1 SD ($SD = 1.43$) below the mean and high enjoyment are 1 SD ($SD = 1.43$) above the mean.

We ran the following model to investigate the relationship between students' persistence (as dependent variable) and students' perception of pedagogies – good teaching (x_5) and progressive teaching (x_6) (as independent variables).

$$\text{Model B: } \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 x_5 + \beta_2 x_6 + e_i$$

The results are shown in Table 22. We found that both good teaching and progressive teaching

Table 22. Students persistence predicted by students' perception of pedagogies

Predictor	Coefficients	SE	Odds Ratio	ρ -value
Intercept	1.37	0.13	0.80	<0.01
Good Teaching	0.51	0.21	0.63	0.01
Progressive Teaching	-0.43	0.20	0.39	0.03

Figure 3. Comparison on the relationship of good teaching and persistence at different level; and comparison on the relationship of progressive teaching and persistence at different level

Notes. Predicted values for low good teaching are 1 SD ($SD = 0.71$) below the mean and high good teaching are 1 SD ($SD = 0.71$) above the mean; Predicted values for low progressive teaching are 1 SD ($SD = 0.75$) below the mean and high progressive teaching are 1 SD ($SD = 0.75$) above the mean.

are statistically significant in predicting students' STEM persistence. Good teaching positively predicted the students' persistence, and progressive teaching negatively predicted the persistence.

At the average level of good teaching and progressive teaching, a student's probability to persist is about 80%. Specifically, as shown in Figure 3, for one standard deviation increase in level of good teaching (SD = 0.71), the probability of persistence increases about 5%; and for one standard deviation increase in level of progressive teaching (SD = 0.75), the probability of persistence decreases about 6%.

Analysis for RQ2

Before addressing the moderation effect, we ran two models to determine whether there were main effects of course type on persistence. After creating two dummy variables to represent version E and version 1A and considering version NE as the reference group, we complete the following two models by including course structures as additional predictors of Model A and Model B described previously:

$$\text{Model C: } \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1x_1 + \beta_2x_2 + \beta_3x_3 + \beta_4x_4 + \beta_5(E) + \beta_6(1A) + e_i$$

$$\text{Model D: } \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1x_5 + \beta_2x_6 + \beta_3(E) + \beta_4(1A) + e_i$$

The completed results of these two models can be found in Appendix I. Results showed that the course structures are statistically significant factors affecting STEM persistence in both models.

In model C, at the average level, a student's probability of STEM persistence in E, 1A, and NE are 96%, 74%, 56% respectively. In addition, the predictor of enjoyment became statistically insignificant. On the other hand, the predictor of confidence became statistically significant. In model D, at the average level, a student's probability of STEM persistence in E, 1A, and NE are 95%, 70%, 54% respectively. Additionally, the significance of the effect of progressive teaching was no longer statistically significant, leaving the good teaching as statistically significant predictor.

Next we examined the moderation effect in RQ2 by examining the following two models by considering the course structures of 1A (z_1) and E (z_2) as moderators, where the variables x_1 to x_6 are beliefs, confidence, attitudes, enjoyment, good teaching, and progressive teaching. The results of these models are reported in Table 23 and Table 24 respectively.

$$\text{Model E: } \ln\left(\frac{p_i}{1-p_i}\right) = (\beta_0 + \beta_5 z_1 + \beta_6 z_2) + x_1(\beta_1 + \beta_7 z_1 + \beta_{11} z_2) + x_2(\beta_2 + \beta_8 z_1 +$$

$$\beta_{12} z_2) + x_3(\beta_3 + \beta_9 z_1 + \beta_{13} z_2) + x_4(\beta_4 + \beta_{10} z_1 + \beta_{14} z_2) + e_i$$

$$\text{Model F: } \ln\left(\frac{p_i}{1-p_i}\right) = (\beta_0 + \beta_3 z_1 + \beta_4 z_2) + x_5(\beta_1 + \beta_5 z_1 + \beta_7 z_2) + x_6(\beta_2 + \beta_6 z_1 +$$

$$\beta_8 z_2) + e_i$$

In the model E, the only statistically significant interaction term (or the moderation effect) is the Confidence: E, and its coefficient is positive. This term indicates that students' effect of confidence on persistence is positively moderated by version E. in other words, student confidence in the version E class had a stronger relationship with persistence than students in NE class. As shown in figure 4, at an average level of confidence, a student in version E has a probability of persistence of 98%. For one standard deviation increases in level of confidence (SD=1.08) of a student in version E, the probability to persist increases about 2%. For one standard deviation decrease in level of confidence of a student in version E, the probability to persist decreases about 6%.

Table 23. Student's persistence prediction with moderation effects

Predictor	Coefficients	SE	Odds Ratio	ρ -value
Intercept	0.30	0.25	0.57	0.22
Beliefs	0.61	0.71	0.65	0.39

Confidence	0.13	0.35	0.53	0.70
Attitudes	0.94	0.46	0.72	0.04
Enjoyment	0.10	0.25	0.52	0.70
E	3.57	0.61	0.97	<0.01
1A	0.73	0.35	0.68	0.04
Beliefs: E	-1.02	1.11	0.26	0.33
Confidence: E	1.20	0.53	0.77	0.02
Attitudes: E	0.39	0.76	0.60	0.60
Enjoyment: E	-0.35	0.36	0.41	0.33
Beliefs: 1A	-0.49	0.96	0.38	0.61
Confidence: 1A	-0.04	0.46	0.49	0.92
Attitudes: 1A	-0.63	0.64	0.35	0.32
Enjoyment: 1A	0.35	0.34	0.59	0.31

Figure 4. Moderation effect in engineering-based course on the relationship of confidence and persistence

Notes. Predicted values for low confidence are 1 SD ($SD = 1.08$) below the mean and high attitudes are 1 SD ($SD = 1.08$) above the mean.

In the model F, the statistically significant interaction terms (moderation effects) is Progressive Teaching: 1A, and its coefficient is positive. It means that students' persistence is positively moderated by their perception of progressive teaching pedagogies in version 1A. The moderation effect for the perception of good teaching pedagogies is not different across three versions. As shown in figure 5 (left side), at an average level of perception of progressive teaching pedagogies, a student in version 1A has a probability of persistence of 72%. For one standard deviation ($SD = 0.75$) increase in level of perception of progressive teaching of a student in version 1A, the probability to persist increases about 7%. Comparing to the persistence probability reference group (version NE) with respect to perception of progressing teaching, we noted that the moderation effect in 1A is very significant.

Table 24. Students persistence predicted by moderation effects

Predictor	Coefficients	<i>SE</i>	Odds Ratio	ρ -value
Intercept	0.34	0.25	0.58	0.17
Good Teaching	1.31	0.46	0.79	<0.01
Progressive Teaching	-1.25	0.49	0.22	0.01
E	2.74	0.44	0.94	<0.01
1A	0.58	0.34	0.64	0.09
Good Teaching: 1A	-1.05	0.63	0.26	0.10
Progressive Teaching: 1A	1.31	0.63	0.79	0.03
Good Teaching: E	-0.14	0.59	0.46	0.82
Progressive Teaching: E	0.85	0.69	0.70	0.22

Figure 5. Moderation Effects in two-semester Calculus I equivalent course and non-engineering course on the relationship of progressive teaching and persistence

Notes. Predicted values for low progressive teaching are 1 SD ($SD = 0.75$) below the mean and high progressive are 1 SD ($SD = 0.75$) above the mean

Discussion and Conclusions

In this paper, we utilize survey tools developed by the national CSPCC project to investigate two research questions within three different Calculus I populations. The first of these focuses on discovering the relationships between students' STEM persistence and students' attributes or perceptions of instructional pedagogies. The second of these focuses on examining the effect of course structures on the predictor's relationship with STEM persistence. We found some factors of students' attributes and students' perceptions of pedagogy predicted STEM persistence in the same way among three course types, but some did not. These observations led us to conclude that the content of course types need to be considered seriously for understanding the relationships between students' persistence and students' attitudes and beliefs or perceptions

of pedagogy. Specifically, there are two conclusions of interest. First, student attributes, such as attitudes and enjoyment, and students' perception of pedagogies are statistically significant factors predicting students STEM persistence; and students' perception of good teaching is more strongly predictive of persistence than progressive teaching. Second, our study provides a more nuanced description of the relationship between students STEM persistence. Specifically, student attitudes and beliefs or perception of pedagogies is not consistent across course sections than previous studies (Bressoud et al., 2013; Sonnert et al., 2015). Course structures cannot be ignored.

We found students' attitudes and enjoyment are significant factors for positively predicting STEM persistence. This result is consistent with the literature (Graham, et al., 2013; Stolle- McAllister, Domingo, & Carriollo, 2011; Summers & Hrabowski, 2014). According to the results of moderation effect analysis, we found that students' attitudes did not predict students' STEM persistence differently between the traditional Calculus I course (the NE version) and two non-traditional Calculus I courses (1A and E versions), nor the two non-traditional Calculus I courses. Moreover, although the prediction of students' confidence of STEM persistence was not different between the traditional version and two-semester version, students' confidence predicted students STEM persistence significantly differently between the non-engineering and the engineering versions.

Ignoring course type, we found that good teaching pedagogies positively predict STEM persistence, but overall progressive teaching pedagogies negatively impact STEM persistence. This result confirms the results found in the CSPCC study (Sonnert et al., 2015) as well as other prior studies that good teaching as perceived by students is more important than progressive teaching for retention. However, based on the results we found on the moderation effect of

perception of pedagogies, we noted that those relationships are different across course types. Our results showed that the prediction of STEM persistence using students' perception of good teaching pedagogies was not different across three course types; however, the prediction of STEM persistence using students' perception of progressive teaching was significantly different between traditional Calculus I and two-semester Calculus I. The relationship of progressive teaching and persistence in NE at low level was statistically significantly stronger than at high level. In contrast, the relationship of progressive teaching and persistence in 1A at low level was close as strong as at high level of progressive teaching.

According to the persistence framework developed by Tinto (1975, 2005) and Graham, et al. (2013), as well as other prior studies, student attributes – such as attitudes, beliefs, confidence, and enjoyment – and the teaching methodologies employed by instructors are important criteria in predicting persistence. Thus, the results from our analyses were able to provide additional insights into these relationships as well as to confirm the original results from other prior studies including the CSPCC findings. We were able to conclude that confidence predicated persistence differently with different content of course structures, but attitudes did not predict persistence differently across course types. The finding may suggest an instructor to focus on using teaching pedagogies that can support or improve engineering major students' confidence during of teaching. We are also able to conclude that effectiveness of an instructor's good teaching methodologies are critical for a population of students who are at the highest risk of failing or withdrawing from a one-semester course. Since the progressive teaching pedagogies are preferred for this group students, an instructor who teaches this type of course need to think carefully using progressive teaching pedagogies in a classroom.

With all these conclusions, it should be noted that our analyses were not cause-effect analyses. We are not able to determine whether students' confidence in engineering Calculus I would stand alone to cause a student to persist in STEM field, nor were we able to determine whether students' perception of progressive teaching pedagogy in two-semester Calculus I would stand alone to cause a student to persist in STEM field. Additional studies need to be conducted to establish the cause and effect relationship of confidence and progressive teaching pedagogy.

In summary, our results complement the outcomes of the CSPCC of Calculus I programs by providing an additional window into the ways in which student attitudes, beliefs and confidence interact with the course structures. Sonnert et al., (2015) found that students' perception interacts with their attitudes and beliefs in complex ways. This study of persistence as related to students' attitude and beliefs provides additional insight into this process. Investigating course structures as moderating factors then uncovered additional ways in which these structural factors interact with student attitudes, beliefs and confidence and then ultimately persistence, moving us closer to a better picture of the complexities found in previous work.

Paper 3: A Exploratory Study on Characteristics of Calculus I Students' Career Decision-Making Strategies

Abstract

College students tend to choose their academic major based on their desired future occupation, and this choice may change depending on how well they progress within that degree program. Students who choose science, technology, engineering and mathematics (STEM) majors, at most institutions, usually take a mathematics course during their first semester. In addition, most STEM-intending students need to finish the calculus sequence in order to complete a STEM major. Much research has shown students' experiences in a calculus course, especially in Calculus I, impacts their decision to remain in a STEM field. In this paper, we sought to investigate the following research question: are there changes in Calculus I students' characteristics of career/major decision making strategies and reasons for switching their decisions after one semester of Calculus I? In this case study, we present an examination of career and major selection choices of students in a first-semester calculus course and how those intentions change over the course of a semester by comparing students' pre- and post-survey responses to a career decision making survey. Between the pre- and post-survey responses, we found differences in their reasons for switching in general as well as differences by gender and STEM classification, but saw no differences in students' responses for why they chose their majors, the attractiveness of their majors, and the characteristics of how they chose their majors over the course of a semester. We focus here on the changes in the reasons why students change their majors.

Keywords: Calculus, Career Decision Making, STEM

Introduction

Many students who leave science, technology, engineering and mathematics (STEM) fields switch to non-STEM majors after taking their introductory STEM classes (Scott, Tolson & Huang, 2009), thus making introductory science and mathematics courses a rich environment for investigating STEM departure. Many of the students who transfer out of STEM majors perform well in these introductory classes (Manhaes, da Cruz, & Zimbrão, 2014) and those who began their postsecondary education in STEM fields proceed to earn bachelor's degrees at a higher rate than those who began in non-STEM fields (Scott, Tolson & Huang, 2009). These findings suggest that many students leaving STEM majors are qualified and, with an increased understanding of the causes of STEM departure, may be an ideal source of successful STEM graduates. The career exploration state of incoming college students is complex. Students can come to college with highly distorted impressions of their chosen profession due to various factors including the lack of authentic role models for scientists and engineers in many communities and by inaccurate portrayals of the profession and members of the profession in popular media. Seymour and Hewitt (1997) identified that students' career or major interest is one of main five factors that can explain student's STEM departure. Understanding the factors that are important in career decision making for calculus students can greatly help in understanding students' STEM departure.

Literature Review

Students generally choose their major when they start their college/university life based on their planned future career (Ferreira, Santos, Fonseca, & Haase, 2006). However, studies have shown that students, especially female students, change their career plans after a semester of Calculus I (Bressoud, Carlson, Mesa, & Rasmussen, 2013; Ellis, Fosdick, & Rasmussen, 2016).

Much research has been conducted to study the characteristics of students' major and career decision making processes and to identify influencing factors. They have found that various intrinsic and extrinsic factors, and combinations of the two, influence major and career choices of students (Borchert, 2002; Bandura, Barbaranelli, Caprara & Pastorelli, 2001; Levine & Hoffner, 2006; McQuaid & Bond, 2003; Millward, Houston, Brown, & Barrett, 2006). Seymour & Hewitt (1997) stressed the complex interplay of intrinsic and extrinsic factors and their influence on career decision making. One of the extrinsic factors that has been reported frequently is the learning environment (Seymour & Hewitt, 1997; Reay, David, & Ball, 2001; Boyd & MacDowall, 2003). For instance, teachers, as one element of the learning environment, play a very influential role in student career choice by providing information and advice about the characteristics of the major and its related future career choices. According to Boyd and MacDowall (2003), students indicated that course teachers are an important source of support in their decisions. Seymour and Hewitt (1997) asserted that a student's learning experience is a critically important factor that impacts a decision to either continue or change their planned major and career, even though its influence on career choice decisions may vary from one population to another.

Current Study

In the fall 2015, collaborating with the Physics department at our institution, a study was conducted to study the characteristics of developmental mathematics students and calculus I students who have declared a STEM major and career intentions. Seven surveys were administered to two cohorts intending to gather information in regards to students' self-efficacy, self-identity status, STEM-belonging, anxiety, personality traits, career decision making process,

etc. The ultimate goal of the study is to build models of successful developmental mathematics and calculus I students in STEM disciplines. In this paper, we focused on the collected data in regards to Calculus I students' career decision making process. Our goal was to examine the characteristics of Calculus I students' career decision making strategies and to explore changes in these characteristics after one semester in a calculus learning environment by answering the research question: are there changes in Calculus I students' characteristics of career/major decision making strategies and reasons for switching their decisions after one semester of Calculus I?

Methods

In the fall semester of 2015, a newly-developed survey was administered twice to a cohort of 1,257 Calculus I students to assess their career decision-making strategies. The survey was constructed based on Brown's (2004) work on identity and Bullock-Yowell, Andrews, & Buzzetta's (2011) work on career decision making process and its relationship to a student's self-efficacy in that context (Pajares and Miller, 1994; Bandura, 1997). The survey was given in the second week, and again in the final week, of the semester. Extra credit was offered as an incentive to encourage completion of the survey. There were 458 calculus students who completed both pre- and post-surveys. Students were more mostly male and STEM intending. Specifically, of the 458 students, only 73 were non-STEM intending students and 150 were female students.

This study specifically focused on analyzing eleven questions that were intended to assess a student's process and reason(s) for choosing a major and career. There were two open-ended questions: *What seems attractive about your current major or career goals?* and *How did you come to decide on your current major?* Completed responses to these two questions from

any of 1,257 students were coded for themes by two members of the research team. Codes were compared until there was total agreement among the researchers and each response was assigned up to three codes. Then there were eight Likert-scale questions (Table 25) following the two open ended questions. The Likert scales were coded with 1- 5, corresponding to options ranging from “Disagree Strongly” to “Agree Strongly”. This survey was developed from prior work (Brown, 2004; Bullock-Yowell, Andrews, and Buzzetta, 2011; Pajares and Miller, 1994; Bandura, 1997) on career identity status and decision making and items were aligned with groupings that correspond to “self-internal” or “family-external”, eight questions were categorized into factors of “self-internal” and “family-external”. Questions Q1-Q4 were categorized to “self-internal”, meaning that students’ characteristics of career/major decision making strategies focused their self-identities status including self-confidence, personal interest, personal enjoyment, etc. Questions Q5-Q8 were categorized to “family-external”, meaning that students’ characteristics of career/major decision making strategies focused the external influences from family such as parents’ desire, parents’ support, etc. The response of these eight

Table 25. Cronbach’s alpha of Question 1 to Question 8

Factors	Items	Cronbach’s alpha
Self-internal	I had difficulty choosing a college major and a future career path.	
	I feel good about my current position with respect to my major.	
	I would be willing to change my current plans if something better came along.	
	I see my occupation as being important to me in my life.	
Family-external	My family's opinion was very important in helping me choose my current major.	
	If my family were supportive, I would be likely to change my major.	
	Most parents have plans for their children; things they'd like them to do or go into. My parents have plans like that for me.	
	My parents feel good about what I'm doing now.	

questions were checked with a Cronbach alpha. The two open ended questions and eight Likert scale questions together were used to explore characteristics of students' career or major decision making strategies.

There was one Yes/No question: *Are you considering changing your major?* that was coded dichotomously with 1 (yes) or 0 (no) respectively. The question was then followed by seven potential reasons for changing major, of which a student could choose as many as were appropriate. A factor analysis was conducted on the seven potential reasons for changing majors and three factors were identified: "loss of interest", "loss of belongingness and expectation" and "lack of confidence". Students' declared majors at beginning of fall semester 2015 and beginning of spring semester of 2016 were retrieved from the university registrar. This information was used to determine a student's classification as either STEM or non-STEM, as well as any changes between the STEM and non-STEM groups.

Results

We began to explore students' characteristics of career/major decision making process by asking students about the attractiveness of their chosen major and their motivations for choosing their major with two open ended questions. The results are shown in Figure 6 and Figure 7. There were not many changes in students' responses to these two statements between the pre- and post-surveys. The majority of students chose their major based on personal interest and some external influence such as family and friends (Figure 6). Many students indicated that they were attracted to their chosen major or career because of anticipated enjoyment or interestingness of the job and an expectation of both financial and personal success (Figure 7).

Figure 6. Student responses to open ended question about factors affecting choice of major or career goals

Figure 7. Student responses to open ended question about attractiveness of major or career goals

We then followed up by asking students about the characteristics of their decision-making process with eight Likert scale questions. These eight questions were categorized into two factors: self-internal and family-external. Pre- and post- survey sample mean comparison of two factors is given in table 26. We observed that students highly agree that they chose their career or major based their self-identities with some external influences such family. These

characteristics of decision-making are consistent with the reasons for choosing their major shown in Figure 6 and Figure 7. In addition, we did not find any statistically significant differences on either factor between pre- and post-survey responses.

Table 26. Sample mean comparison between factors of characteristics of career decision making

Factors	Pre-survey		Post-survey		t-test result		
	Mean	SD	Mean	SD	t-statistics	df	p-value
Self-Internal	3.84	0.50	3.81	0.56	-0.91	457	0.36
Family-External	3.26	0.70	3.21	0.70	-1.09	457	0.27

We also asked students if they planned to change their major both at the beginning of the semester and at the end of the semester. The results are reported in Figure 8. At the beginning of the semester, 21.27% of students planned to change majors and 19.74% indicated they planned to change at the end of the semester. By using institutional information about students' declared majors at beginning and end of the semester, we found that a substantially high percentage of these students did, indeed, change their major after a semester in a mathematics course, though it was still a relatively small percentage of total students (12.81% of 458 students in the study). We designate these students as “switchers” (Bressoud, Carlson, Pearson, Rasmussen, 2012) and the switch rate as 12.81%.

Figure 8. Percentage of students intending to change major by survey response and actual switch rate of students

Students who indicated an intent to change majors at the beginning of the term described different reasons for doing so (Table 27) than those who indicated a desire to switch at the end of the semester. As shown in Table 26, the critical reason for change for students at the beginning of the term were a loss of interest and a loss of belongingness and expectation in their current major. By examining the reasons for changing majors at the end of the term, similar patterns with some exceptions were discovered (Table 26). A loss of interest is still a critical reason for

Table 27. Pre- and post-survey comparisons for reasons for change-population indicating major change intention.

Factors	Pre-survey	Post-survey
Loss of interest	61%	60%
Loss of belongingness and expectation	62%	74%
Lack of confidence	17%	46%

switch, although there is a statistically insignificant small decrease. There is a statistically significant increase in the percentage of students indicating a loss of belongingness and expectation as an important reason for switch. More importantly, a decrease in confidence appeared as an important reason for switching at the end of the semester three times as often as at the beginning of the semester.

Considering students by gender (Figure 9), we found an increase in the number of female switchers from beginning to end of the semester, while the number of male switchers decreased in that time. The data also show that the female intended switch rates are lower than those for males. The actual switch rates are much lower than the intended pre- and post-survey rates for both male and female students.

Figure 9. Percentage of students intending to change major by survey response and actual switch rate of students by gender.

Considering student responses by STEM classification (Figure 10), we found there was an increase in the number of non-STEM intending students planning to switch, while the numbers of STEM intending switchers decreased. The data also show that the actual non-STEM

switch rate is lower than STEM switch rate and the actual switch rates are much lower than the intended pre- and post-survey rates for both categories.

Figure 10. Percentage of students intending to change major by survey response and actual switch rate of students by STEM classification

Comparing reasons for switching in pre- and post-surveys by gender and STEM classification, we want to find whether there are differences within each category. In Table 28, we examine pre- and post-survey responses by gender and in Table 29 we examine pre- and post-survey responses by STEM classification.

We see that both male and female switchers indicate a loss of interest, a loss of belongingness and expectation and a lack of confidence as major factors for switching. The differences in all three factors between male and female switchers are not statistically significant in pre-survey. The differences in factors of loss of interest and loss of belongingness and expectation between male and female are still not statistically significant in post-survey. However, there is a statistically significant larger number of female students than male students indicating a lack of confidence as a reason. Moreover, there is a statistically significant increase in number of male and female students who indicated a loss of belongingness and expectation as critical from the pre- to the post-survey, and a statistically significant increase in number of

female students indicating a lack of confidence as an important reason for changing from the pre- to the post-survey.

Table 28. Switchers' reasons for changing major during pre- and post-survey by gender

Factor	Pre-survey		Post-survey	
	Female	Male	Female	Male
loss of interest	56%	63%	55%	62%
loss of belongingness and expectation	64%	61%	76%	73%
lack of confidence	44%	43%	59%	42%

Both STEM and non-STEM intending switchers (Table 29) indicated in the pre-survey that a loss of interest and a loss of belongingness and expectation were significant reasons for

Table 29. Switchers' reasons for changing major during pre- and post-survey by STEM classification

Factors	Pre-survey		Post-survey	
	STEM	non-STEM	STEM	non-STEM
loss of interest	63%	50%	61%	53%
loss of belongingness and expectation	59%	83%	76%	67%
lack of confidence	45%	33%	43%	59%

them to switch majors. STEM students also indicated a lack of confidence as a considerable reason for switching (45%), but non-STEM students did not consider it as important (33%). In the post-survey, STEM students indicated same reasons for switching as in the pre-survey. Non-

STEM students also indicated the same reasons as well, but a lack of confidence became significant (59%) in the post-survey. The differences in all three factors between STEM and non-STEM intending switchers are statistically significant in both the pre- and the post-surveys. From pre-survey to post-survey, there is a statistically significant increase in number of STEM intending switchers indicating a loss of belongingness and expectation as a reason. From pre-survey to post-survey, there is a statically significant increase in number of non-STEM intending switchers indicating a lack of confidence as reason but a statistically significant decrease in number of non-STEM intending switchers indicating a loss of belongingness and expectation.

Conclusions

In this case study, a career exploration survey was utilized to investigate a research question focusing on finding the differences in, and factors influencing, Calculus I students' career/major decision making strategies after one semester of Calculus I. The findings in this case study showed that there are no pre- and post-survey differences in students' reasons for choosing their major, beliefs towards the attractiveness of their major, and the characteristics of how they chose their major, but there are distinct differences in reasons for switching major between pre- and post- surveys. These findings are summarized to conclude that a one-semester learning experience did not change students' attitude and beliefs towards choosing their major/career plan, though there were differences in what beliefs supported their attitudes towards major changes.

The two open-ended questions and eight Likert scale questions in the surveys were designed to examine students' choice of major, beliefs towards the attractiveness of their major, and the characteristics of how they chose their major. The study found no differences in students' responses on these ten questions. However, the study did find that students had

different reasons for changing major or career goals after a one semester learning experience in Calculus I and a difference in switch rate from beginning of semester to end of semester. Losing interest, losing a sense of belongingness and expectation and lacking confidence were shown to be influential reasons for students changing their major or career plans. These conclusions are consistent with current literature.

Considering gender and STEM classification, the learning experience impacted female students more than male students and impacted STEM intending students more than non-STEM intending students. Female students and non-STEM students tended to find the factors of losing interest and confidence as reason of switching major more severe than male students. Female students also indicated that a sense of belonging to their major is very important impacting factor for changing their major.

With all these conclusions, the study is not able to draw any correlations or cause and effect conclusions since the found results are exploratory. The scales of each response items were not subjected to a full psychometric review, and a future study need to be conducted to examine the reliability and validity of the subscale scores. Further studies need to be conducted to determine the causes of changes in the characteristics of student's major or career decision making strategies and causes of reasons for switching planned major or career. Even more importantly, what role(s) of these changes played in impacting a student's STEM intention should a very interesting research questions that need to be answered.

Acknowledgement

Partial support for this work was provided by the National Science Foundation's Improving Undergraduate STEM Education (IUSE) program under Award No. 1544011. Any opinions,

findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Chapter 4. Dissertation Conclusions

The purpose of this dissertation was to examine how first semester calculus students' learning experiences are related to their STEM intentions. The following three research questions guided the development of the study and the subsequent analysis of the data.

1. Do different learning experiences in Calculus I influence students' attitudes and beliefs differently? Are there similarities and/or differences in students' attitudes and beliefs toward mathematics across the different versions of Calculus I offered at the local institution and how does my local data compare to the national data?
2. Is Calculus I students' STEM persistence predicted by students' attitudes & beliefs or perception of pedagogies? Is this relationship between persistence and students' attitudes and beliefs or perception of pedagogies moderated by the different structures of the Calculus I course?
3. Are there differences in a student's level of decisiveness with which they chose their majors and their reasons for changing majors and/or careers (if applicable) across the different versions of Calculus I at the local institution? How are these differences associated with STEM persistence?

These three groups of research questions loosely correspond to three different focuses through which the research community can examine the persistence and characteristics of first semester calculus students in STEM disciplines.

The first lens is focused on the effect of students' learning experiences on students' attributes including attitudes, beliefs, confidence, and enjoyment that students perceived during one semester of Calculus I learning experiences. In this dissertation, I first specifically focused on the exploration of similarities and differences of students' attributes in three different versions of Calculus I and the comparison of local data to the national CSPCC data. I then established a

result that the discovered differences and similarities were due to different learning experiences, not students' academic backgrounds. The results of this analysis were presented in Paper 1 that is under review (Wu, Deshler, & Fuller, under revision).

The second lens pertains to students' STEM persistence. Based on the findings from the first paper, it seemed that students had different learning experiences across different course structures. Thus, encouraged by the findings in first paper, I started to examine the effectiveness of three different course structures. Specifically, I started to investigate the role of course structures involved in the relationship between student STEM persistence and students' attributes or students' perception of pedagogies. The results of this analysis were presented in Paper 2 that is currently under review (Wu, Rambo-Hernandez, Fuller, & Deshler, under review).

Finally, the third lens specified on a small portion of a big picture of student persistence. I focused on examine students' characteristics of major or career exploration during of one semester Calculus I learning experience. My goal was to examine the characteristics of Calculus I students' career decision making strategies and to explore whether there are changes in these characteristics after one semester in a calculus learning environment. The results of this analysis were presented in Paper 3 that is currently under review (Wu & Deshler, in preparation).

The three papers in this dissertation are followed from one to another. Initial analysis designed to answer the first research question focused on the examination of effect of course structures on students' attributes toward mathematics including attitudes, beliefs, enjoyment, confidence and desire for more mathematics. In this paper, we pinpointed differences and similarities of students' attributes across three versions of Calculus I and between local data and national data (E, NE, and 1A). We found that student learning experiences in three versions of Calculus I have an effect on both their beliefs and attitudes toward mathematics. Moreover, the

impact of the course structures is different, and we were able to isolate the impacts within course structures from the student demographic backgrounds within those structures, implying that some aspects of the course experiences themselves are responsible for these differences.

The second research question was encouraged by conclusions of first research question. Since the impact of the course structures is different, we were wondering what role of course structures is and so we framed our second research questions focusing on the effectiveness of course structures. To answer the second research questions, we developed six logistic models that were used to test relationships between student STEM persistence and students' attributes or students' perception of instructional pedagogies, and the moderation effect of course settings. The results of these six models led us to make two conclusions. First, student attributes, such as attitudes and enjoyment, and students' perception of pedagogies are statistically significant factors predicting students STEM persistence; and students' perception of good teaching is more strongly predictive of persistence than progressive teaching. Second, the relationship between students STEM persistence and student attitudes and beliefs or perception of pedagogies is not consistent across course sections. Course structures cannot be ignored. Specifically, students' attitudes and enjoyment are significant factors for positively predicting STEM persistence; and by considering course structures, students' attitudes did not predict students' STEM persistence differently between the traditional Calculus I course (the NE version) and two non-traditional Calculus I courses (1A version and E version), nor between the two non-traditional Calculus I courses, but students' confidence predicted students STEM persistence significantly differently between the traditional version and the engineering version. Good teaching pedagogies positively predict STEM persistence, but progressive teaching pedagogies negatively impact STEM persistence; and by considering course structures, the prediction of STEM persistence using

students' perception of good teaching pedagogies was not different across three course types, however, the prediction of STEM persistence using students' perception of progressive teaching was significantly different between traditional Calculus I and two-semester Calculus I. The relationship of progressive teaching and persistence in NE at low level was statistically significantly stronger than at high level. In contrast, the relationship of progressive teaching and persistence in 1A at low level was close as strong as at high level of progressive teaching.

The third paper was designed to be a brief research paper, in line with the third research questions. In this paper I analyzed eleven questions that were intended to assess a Calculus I student's process and reason(s) for choosing and switching a major and career from a career survey, which was given to student at beginning and at end of a semester. I first compared student's reasons choosing their major or career goals to identify factors that influence their major or career decision making. I then explored characteristics of students' career or major decision making strategies. Finally, I compared student's reasons for switching their major or career goals regard and regardless of gender and STEM classifications. We found that there are no pre- and post-survey differences in students' reasons for choosing their major, beliefs towards the attractiveness of their major, and the characteristics of how they chose their major, but there are distinct differences in reasons for switching major between pre- and post- surveys regard and regardless of gender and STEM classifications. These findings are summarized to conclude that a one-semester learning experience did not change students' attitude and beliefs towards choosing their major/career plan, though there were differences in what beliefs supported their attitudes towards major changes.

By focusing on the effect of course structures on the relationships among students' attributes, students' perceptions of pedagogies and students STEM persistence, this dissertation

provides important and new information for understanding student STEM retention issue as well contributing some insights for developing a successful Calculus program. We cannot neglect the impact of course structure. The findings from this dissertation complement the established outcomes in literature including CSPCC of Calculus I programs by providing an additional window into the ways in which student attitudes, beliefs and confidence interact with the course structures. This dissertation study of persistence as related to students' attitude and beliefs and perceptions of pedagogies provides additional insights understanding student retention.

Investigating course structures as moderating factors then uncovered additional ways in which these structural factors interact with student attitudes, beliefs and confidence and then ultimately persistence, moving us closer to a better picture of the complexities found in previous work.

Chapter 5. Future Work

This dissertation focused very specifically on Calculus I student STEM persistence, attitudes and beliefs, and perceptions of pedagogies. While most students pursuing a degree in STEM field need to complete the sequence of Calculus, it is therefore necessary to extend the investigations to the larger sequence of Calculus classes to have a better understanding STEM retention. Moreover, as identified in the literature, there are many other factors, besides student's attitudes and beliefs and perceptions of pedagogies, which can affect the student STEM persistence. Therefore, it will be very necessary to include other factors such as students' sense of STEM belongings, self-efficacy, anxiety, etc. when one tries to develop a more complete framework for understanding the retention issues.

Furthermore, as indicated in all three papers, many of our conclusions are not cause and effect conclusions. For instance, in paper 2, we are not able to determine whether students' confidence in engineering Calculus I would stand alone to cause a student to persist in a STEM field, nor were we able to determine whether students' perception of progressive teaching pedagogy in two-semester Calculus I would stand alone to cause a student to persist in a STEM field; in paper 3, we did not determine the causes of changes in the characteristics of student's major or career decision making strategies and causes of reasons for switching planned major or career, nor what role(s) of these changes played in impacting a student's STEM intention. These indeterminations raise many interesting research questions that need to be answered.

Lastly, the findings from this dissertation may provide many useful information and suggestions for re-designing Calculus I curriculum and classroom teaching. However, conclusions do not particularly provide many specific instructions how to implement these

suggested teaching implications and how to use them in development of curriculum. It will be very meaningful to conduct some design of experiments to test these conclusions.

Chapter 6. Bibliography

- Alexander, L., & Martray, C. (1989). The Development of an Abbreviated Version of the Mathematics Anxiety Rating Scale. *Measurement and Evaluation in Counseling and Development*, 22(3), 143-50.
- Anderson, T.H. (1995). *The Movement and Sixties*. Oxford University Press. New York, NY.
- Ashcraft, M. H., & Krause, J. A. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin & Review*, 14 (2), 243-248.
- Astin, A. W. (1993). *What Matters in College? Four Critical Years Revisited* (Vol. 1). San Francisco: Jossey-Bass.
- Astin, A.W. (1997). How “good” is your institution’s retention rate? *Research in Higher Education*. 38(6), 647-658.
- Atadero, R. A., Rambo-Hernandez, K. E., & Balgopal, M. M. (2015). Using social cognitive career theory to assess student outcomes of group design projects in statics: SCCT and student outcomes of statics projects. *Journal of Engineering Education*, 104(1), 55-73.
- Bandura, A., Barbaranelli, C., Caprara, G., and Pastorelli, C. (2001). Self-efficacy beliefs as shapers of children’s aspirations and career trajectories. *Child development*, 72(1), 187-206.
- Bean, J.P. (1980). Dropouts and turnover: the synthesis and test of a causal model of student retention. *Research in Higher Education*, 12 (2), 155-187.
- Borchert, M. (2002). *Career Choice Factors of High School Students* (Unpublished Master of Science thesis). University of Wisconsin-Stout.

- Boyd, S., & MacDowall, S. (2003, November). Innovative pathways from secondary school: Gaining a sense of direction. In *NZARE/AARE Conference: 29 November-3 December 2003. Auckland, New Zealand*.
- Bressoud, D. 2015. Insights from the MAA National Study of College Calculus. *Mathematics Teacher*. 109 (3), 179–185.
- Bressoud, D., Carlson, M., Mesa, V., & Rasmussen, C. (2013). The Calculus Student: Insights from the MAA National Study. *International Journal of Mathematical Education in Science and Technology*. 44(5), 685–698.
- Bressoud, D., Carlson, M., Pearson, J.M., & Rasmussen, C. (2012). Preliminary Results of the Study on Characteristics of Successful Programs in College Calculus. *ICME12*.
- Bressoud, D., Mesa, V., Rasmussen, C. (Eds.). (2015). *Insights and Recommendations from the MAA National Study of College Calculus*. MAA Press.
- Brown, S.D., Tramayne, S., Hoxha, D., Telander, K., Fan, X., & Let, R.W. (2008). Social cognitive predictors of college students' academic performance and persistence: A meta-analytic pay analysis. *Journal of Vocational Behavior*, 72(3), 298-308.
- Brown, S.V. (1994). Under-represented Minority Women in Science and Engineering Education. *Princeton, NJ: Educational Testing Service*.
- Burroughs, E.A., & Deshler, J.M., (2013). Gender Bias? *The College Mathematics Journal*, 44 (2).
- Burtner, J. (2005). The Use of Discriminant Analysis to Investigate the Influence of Non-Cognitive Factors on Engineering School Persistence. *Journal of Engineering Education*, 94(3), 335–338.
- Carlone, H.B. (2004). The cultural production of science in reform-based physics: girls' access, participation and resistance. *Journal of research in Science Teaching*, 41(4), 392-414.

- Carlson, M. (1999). The mathematical behavior of six successful mathematics graduate students: Influences leading to mathematical success. *Educational Studies in Mathematics*, 40(3), 237-258.
- Carlson, M. P., & Bloom, I. (2005). The cyclic nature of problem solving: An emergent multidimensional problem-solving framework. *Educational Studies in Mathematics*, 58(1), 45-75.
- Carlson, M., Bloom, I., & Glick, P. (2008). Promoting effective mathematical practices in students: insights from problem solving research. In *Making the Connection: Research and Teaching in Undergraduate Mathematics Education*. Mathematical Association of America.
- Carlson, M., Buskirk, T., & Halloun, I. (1999). Assessing college student's views about mathematics with the views about mathematics survey. *Educational Studies in Mathematics*, 40(3), 237-258.
- Carnevale, A.P., Smith, N., & Melton, M. (2011). STEM: Science, technology, engineering, mathematics. *Georgetown University Center on Education and the Workforce*.
- Chang, M. J., Sharkness, J., Hurtado, S., & Newman, C. B. (2014). What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups? *Journal of Research in Science Teaching*, 51(5), 555-580.
- Chang, M., Eagan, K., Lin, M., & Hurtado, S. (2011). Considering the Impact of Racial Stigmas and Science Identity: Persistence among Biomedical and Behavioral Science Aspirants. *Journal of Higher Education*, 82(5), 564-596.
- Chen, X., & Soldner, M. (2013). STEM Attrition: College students' path into and out of STEM fields. Statistical Analysis Report. NCES 2014-001. *National Center for Education Statistics*.

- Cheryan, S., Master, A., & Meltzoff, A. N. (2015). Cultural stereotypes as gatekeepers: Increasing girls' interest in computer science and engineering by diversifying stereotypes. *Frontiers in Psychology*, 6, 49.
- Cobb, P. (1986). Contexts, Goals, Beliefs and Learning Mathematics. *For the Learning of Mathematics*, 6(2), 2-9.
- Cobb, P., & Bauersfeld, H. (Eds.). (1995). *The emergence of mathematical meaning: Interaction in classroom cultures*. Psychology Press.
- Cobb, P., & Yackel, E. (1996). Constructivist, emergent, and sociocultural perspectives in the context of developmental research. *Educational Psychologist*, 31(3/4), 175-190.
- Deshler, J., & LaClair, C., (in preparation) Gender, Grade Point Average and Self Selection out of College Mathematics Classes. *International Journal of Gender, Science and Technology*.
- Deshler, J., Miller, D., & Pascal, M. (2016). An Active Classroom: The Emerging Scholars Program at West Virginia University. *PRIMUS*, 26 (9), 811-823.
- Dey, E.L. (1990). Evaluating college student retention: comparative national data from the 1981-1984 entering freshmen classes. In *annual meeting of the American Educational Research Association*, Boston, MA.
- Eagan, K., Hurtado, S., & Chang, M. (2010). What matters in STEM: Institutional contexts that influence STEM bachelor's degree completion rates. In *annual Meeting of the Association for the Study of Higher Education*, Indianapolis, IN.
- Elkins, S., Braxton, J., & James, G. (2000). Tinto's separation stage and its influence on first-semester college student persistence. *Research in higher education*, 41(2), 251-268.

- Ellis, J., & Cooper, R. (2016). Gender, switching, and student perceptions of Calculus I. In *19th Annual Conference on Research in Undergraduate Mathematics Education, Pittsburgh, PA*.
- Ellis, J., Fosdick B. K., & Rasmussen, C. (2016). Women 1.5 Times More Likely to Leave STEM Pipeline after Calculus Compared to Men: Lack of Mathematical Confidence a Potential Culprit. *PLOS ONE*, *11*(7): e0157447.
- Ellis, J., Hanson, K., Nuñez, G., & Rasmussen, C. (2015). Beyond Plug and Chug: An Analysis of Calculus I Homework. *International Journal of Research in Undergraduate Mathematics Education*, *1*(2), 268-287.
- Ellis, J., Kelton, M., & Rasmussen, C. (2014). Student perceptions of pedagogy and associated persistence in calculus. *ZDM – The International Journal on Mathematics Education*, *46*(4), 661-673.
- Ellis, J., Rasmussen, C., & Fosdick, B. (2015). Qualified and interested females decrease STEM intentions following first-year calculus at much higher rates than male, Why? In preparation.
- Ernest, P. (1998). *Social Constructivism as a Philosophy of Mathematics*. Suny Press.
- Espinosa, L. L. (2011). Pipelines and pathways: Women of color in undergraduate STEM majors and the college experiences that contribute to persistence. *Harvard Educational Review*, *81*(2), 209–240.
- Ethington, C. (2000). Influences of the normative environment of peer groups on community college students' perception of growth and development. *Research in Higher Education*, *41*(6), 703-722.

- Farmer, H.S. (1997). Women's motivation related to mastery career salience, and career aspiration: a multivariate model focusing on the effect on sex role socialization. *Journal of career assessment*, 5(4), 355-381.
- Fennema, E., & Sherman, J.A. (1976). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by female and males. *Journal for Research in Mathematics Education*, 7(5), 324-326.
- Ferreira, J. A., Santos, E. J. R., Fonseca, A. C. & Haase, R. F. (2006). Early predictors of career development: A 10-year follow-up study. *Journal of Vocational Behavior*, 70(1), 61-77.
- Froyd, J. E., Wankat, P. C., & Smith, K. A. (2012). Five major shifts in 100 years of engineering education. *Proceedings of the IEEE*, 100 (Special Centennial Issue), 1344-1360.
- Giffi, C., Dollar, B., Drew, M., McNelly, J., Carrick, G., & Gangula, B. (2015). The skills gap in U.S. manufacturing 2015 and beyond. *Washington, DC: Deloitte and Manufacturing Institute*.
- Goldin, G.A. (2004). Problem solving heuristics, affect and discrete mathematics. *ZDM*, 36(2), 56-60.
- Good, C., Rattan, A., & Dweck, C., (2012) Why Do Women Opt out? Sense of Belonging and Women's Representation in Mathematics, *J. Personality and Social Psychology*, 102(4), 700-717.
- Graham, M. J., Frederick, J., Byars-Winston, A., Hunter, A. B., & Handelsman, J. (2013). Increasing persistence of college students in STEM. *Science*, 341(6153), 1455-1456.
- Graham, R. (2010). UK approaches to engineering project based learning. *White Paper sponsored by the Bernard M. Gordon/MIT Engineering Leadership Program*. <http://web.mit.edu/gordonelp/ukpjblwhitepaper2010.pdf>.

- Griffith, A.L. (2010). Persistence of women and minorities in STEM field majors: Is it school that matters? *Economics of Education Review*, 29(6), 911-922.
- Hannula, M. (2012). Exploring new dimensions of mathematics-related affect: embodied and social theories. *Research in Mathematics Education*, 14(2), 137-161.
- Hembree, R. (1990). The nature, effects and relief of mathematics anxiety. *Journal for Research in Mathematics Education*, 33-46.
- Henderson, C., Beach, A., & Finkelstein, N. (2011). Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *Journal of Research in Science Teaching*, 48(8), 952-984.
- Hunter, A., Thiry, H., Holland, D., Harper, R., Seymour, E. (2016). Talking about leaving revisited – a multi-component research study exploring factor influencing undergraduate switching from STEM major. Retrieved from <http://www.aplu.org/projects-and-initiatives/stem-education/science-and-mathematics-teaching-imperative/smti-conferences-meetings/SMTI%202016%20National%20Conference/Hunter-Poster.pdf>.
- Hurtado, S., Eagan, K., & Chang, M. (2010). Degrees of success: Bachelor's degree completion rates among initial STEM majors. *Higher Education Research Institute at UCLA, January..*
- Islam, M. M., & Al-Ghassani, A. (2015). Predicting college math success: Do high school performance and gender matter? Evidence from Sultan Qaboos University in Oman. *International Journal of Higher Education*, 4(2), 67.
- Jensen, U. (2011). *Factors Influencing Student Retention in Higher Education. Summary of Influential Factors in Degree Attainment and Persistence to Career or Further Education for At-Risk/High Educational Need Students*. Honolulu, HI: Pacific Policy Research Center, Kamehameha Schools–Research & Evaluation Division.

- Johnson, E., Ellis, J., & Rasmussen, C. (2015). It's About Time: The Relationships between Coverage and Instructional Practices in College Calculus. *International Journal of Mathematical Education in Science and Technology*, 47(4), 491-504.
- Kamens, D.H. (1971). The college "charter" and college size: effects on occupational choice and college attrition. *Sociology of Education*, 270-296.
- Kim, M. M., Rhoades, G., & Woodard, D. B. (2003). Sponsored research versus graduating students Intervening variables and unanticipated findings in public research universities. *Research in Higher Education*, 44 (1), 51-81.
- Kolmos, A., & Graaff, E. (2014). Problem-based and project-based learning in engineering education – Merging models. *Cambridge hand-book of engineering education research*, 141–160
- Kuh, G., Cruce, T., Shoup, R., Kinzie, J., & Gonyea, R. (2008). Unmasking the effects of student engagement on fire-year college grades and persistence. *The Journal of Higher Education*, 79(5), 540-563.
- Lau, L. K. (2003). Institutional factors affecting student retention. *Education-Indianapolis then Chula Vista-*, 124(1), 126-136.
- Leder, G. C., & Forgasz, H. J. (2002). Measuring mathematical beliefs and their impact on the learning of mathematics: A New Approach. In *Beliefs: A hidden variable in mathematics education?* (pp.95-113).Springer, Dordrecht.
- Lent, R. W., Brown, S.D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior*, 45(1), 79-122.

- Lent, R.W., Brown, S.D., Schmidt, J., Brenner, B., Lyons, H., & Treistman, D. (2003). Relation of contextual supports and barriers to choice behavior in engineering majors: Test of alternative social cognitive modes. *Journal of Counseling Psychology*, 50(4), 458-465.
- Lent, R.W., Brown, S.D., Sheu, H.-B., Schmidt, J., Brenner, B.R., Gloster, C.S., & Treistman, D. (2005). Social cognitive predictors of academic interest and goals in engineering: Utility for women and students and historically black universities. *Journal of Counseling Psychology*, 52(1), 84-92.
- Levine, K. J., & Hoffner, C. A. (2006). Adolescents' Conceptions of Work: What Is Learned From Different Sources During Anticipatory Socialization? *Journal of Adolescent Research*, 21(6), 647-669.
- Lewis, G. (2013). Emotion and disaffection with school mathematics. *Research in Mathematics Education*, 15(1), 70-86. 37-41.
- Lindberg, S. M., Hyde, J. S., Petersen, J. L., & Linn, M. C. (2010). New trends in gender and mathematics performance: a meta-analysis. *Psychological bulletin*, 136(6), 1123.
- Litzler, E., & Young, J. (2012). Understanding the risk of attrition in undergraduate engineering: Results from the project to assess climate in engineering. *Journal of Engineering Education*, 101(2), 319-345.
- Main, R. (2004). *The rupture of time: Synchronicity and Jung's critique of modern western culture*. Routledge.
- Manhaes, L. M. B., da Cruz, S. M. S., & Zimbrão, G. (2014). Investigating withdrawal of STEM courses in a Brazilian university with EDM. In *2nd Symposium on Knowledge Discovery, Mining and Learning (KDMILE)*.

- Marcus, R. D. (1989). Freshmen retention rates at U.S. private colleges: Results from aggregated data. *Journal of Economic and Social Measurement*, 15(1), 37-55.
- Matsui, J., Liu, R., & Kane, C. M. (2003). Evaluating a science diversity program at UC Berkeley: more questions than answers. *Cell Biology Education*, 2(2), 117–121.
- Mattern, K., Radunzel, J., & Westrick, P. (2015). Development of STEM readiness benchmarks to assist educational and career decision making. ACT Research Report Series, 2015 (3). *ACT, Inc.*
- McLeod, D. B. (1992). Research on affect in mathematics education: A reconceptualization. *Handbook of Research on mathematics teaching and learning*, 575-596.
- McQuaid, R. & Bond S. (2003). Gender stereotyping of Career choice.
- Millward, L., Houston, D., Brown, D., & Barrett, M. (2006). Young People’s Job Perceptions and Preferences. *Department of Trade and Industry*.
- Morgan, W. A. (1939). A test for the significance of the difference between the two variances in a sample from a normal bivariate population. *Biometrika*, 31(1/2), 13-19.
- Morrison, T., Maciejewski, B., Giffi, C., DeRocco, E. S., McNelly, J., & Carrick, G. (2011). Boiling point? The skills gap in U. S. manufacturing. *Deloitte and The Manufacturing Institute*.
- Morrison, C., & Williams, L.E. (1993). Minority engineering programs: a case for institutional support. *NACME Research Newsletter*, 4(1), n1.
- Mortenson, T.G. (1995). Financing opportunity for postsecondary-education. In *NACME Research and Policy Conference: Minorities in Mathematics, Science and Engineering*, Wake Forrest University. Wake Forest, NC, Jan. 26-29.

- National Academy of Engineering (NAE). (2004). *The engineer of 2020: Visions of engineering in the new century*. Washington, DC: National Academies Press.
- National Academy of Engineering (NAE). (2005). *Educating the engineer of 2020: Adapting engineering education to the new century*. Washington, DC: National Academies Press.
- National Center for Education Statistics (NCES). (2008). *Digest Education Statistics 2008*. Retrieved from <http://www.nces.ed.gov/pubs2009/2009020.pdf>
- National Research Council (NRC). (1995). *Engineering education: Designing an adaptive system*. Washington, DC: National Academies Press. Retrieved from: http://www.nap.edu/openbook.php?recrod_id=4907.
- National Research Council (NRC). (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press. Retrieved from: http://www.nap.edu/openbook.php?record_id=11463.
- National Research Council (NRC). (2010). *Rising above the gathering storm, revisited: Rapidly approaching Category 5*. Washington, DC: National Academies Press. Retrieved from http://www.nap.edu/openbook.php?record_id=12999.
- National Science Board (NSB). (2007). *Moving forward to improve engineering education*. Arlington, VA.: National Science Foundations. Retrieved from <http://www.nsf.gov/pubs/2007/nsb07122/nsb07122.pdf>.
- National Science Foundation (NSF). (2007). *Women, Minorities, and persons with disabilities in science and engineering* (NSF 07 – 315). Arlington, VA: Authors.
- National Science Foundation. (2014). *Science and engineering indicators 2014*. NSF, National Science Foundation, 14-60.

- Noel-Levitz. (2013). National Freshman Attitudes Report: Exploring college readiness among today's entering freshmen. Cedar Rapids, Iowa. Retrieved from <https://www.noellevitz.com/papers-research-higher-education/2013/2013-national-freshman-attitudes-report>.
- Ormrod, J. E. (2006). *Educational psychology: Developing learners* (5th ed.). Upper Saddle River, N.J.: Pearson/Merrill Prentice Hall.
- Pajares, F., & Miller, D. (1995). Mathematics self-efficacy and mathematics performances: The need for specifically of assessment. *Journal of counseling psychology*, 42(2), 190.
- Pascarella, E. T., & Terenzini, P. T. (1980). Predicting Freshman Persistence and Voluntary Dropout Decisions from a Theoretical Model. *The Journal of Higher Education*, 51(1), 60.
- President's Council of Advisors on Science and Technology (PCAST) (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*. Washington, D.C.: Office of Science and Technology Policy.
- Price, J. (2010). The Effect of Instructor Race and Gender on Student Persistence in STEM Fields. *Economics of Education Review*, 29(6), 901–910.
- Rasmussen, C., & Ellis, J. (2013). Who is switching out of calculus and why? In *Proceedings of the 37th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 73-80).
- Reay, D., David, M., & Ball, S. (2001). Making a difference? Institutional habituses and higher education choice. *Sociological Research Online*, 5(4), 1-12.
- Rogers, W. D., & Ford, R. (1997). Factors that affect student attitude toward biology. *Bioscene*, 23(2), 3-5.

- Sadker, D., Sadker, M., & Zittleman, K.M. (2009). *Still failing at fairness: how gender bias cheats girls and boys in school and what we can do about it*. Simon & Schuster.
- Saupe, J. L., Smith, T. Y., & Xin, W. (1999, May). Institutional and student characteristics in student success: First-term GPA, one-year retention and six-year graduation. In *annual Association for Institutional Research, Seattle, WA*.
- Schoenfeld, A. H. (1989). Explorations of students' mathematical beliefs and behavior. *Journal for research in mathematics Education*, 20(4), 338- 335.
- Schoenfeld, A.H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense-making in mathematics. *Handbook for Research on Mathematics Teaching and Learning*, 334-370.
- Schommer, M., Calvert, C., Gariglietti, G., & Bajaj, A. (1997). The development of epistemological beliefs among secondary students: A longitudinal study. *Journal of Educational Psychology*, 89(1), 37-40.
- Schommer-Aikins, M., Duell, O.K., & Hutter, R. (2005). Epistemological Beliefs, Mathematical Problem-Solving Beliefs, and Academic Performance of Middle School Students. *The Elementary School Journal*, 105(3), 289-304.
- Science editorial. (1992). Minorities in science: the pipeline problem. *Science*, 258 (5085), 1175-1175.
- Scott, T. P., Tolson, H., & Huang, T. (2009). Predicting retention of mathematics and science majors at a Research One Institution and Suggested Advising Tools. *Journal of College Admission*, 204, 20–24.
- Seymour, E. (2002). Tracking the processes of change in US undergraduate education in science, mathematics, engineering, and technology. *Science Education*, 86(1), 79-105.

- Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving: why undergraduates leave the sciences*. Boulder, Colo: Westview Press.
- Shakeshaft, C. (1995). Reforming Science education to include girls. *Theory into Practice*, 34(1), 74-79.
- Shapiro, C. A., & Sax, L. J. (2011). Major selection and persistence for women in STEM. *New Directions for Institutional Research*, 2011(152), 5-18.
- Sithole, A., Chiyaka, E. T., McCarthy, P., Mupinga, D. M., Bucklein, B. K., & Kibirige, J. (2017). Student Attraction, Persistence and Retention in STEM Programs: Successes and Continuing Challenges. *Higher Education Studies*, 7(1), 46.
- Sjoberg, C. E. (1999). *The Relationship of Environmental Predictors and Institutional Characteristics to Student Persistence* (Unpublished doctoral dissertation). Oklahoma State University, OK.
- Soldner, M., Rowan-Kenyon, H., Inkelas, K.K., Garvey, J., & Robbins, C. (2012). Supporting students' intentions to persist in STEM disciplines: The role of living-learning programs among other social-cognitive factors. *Journal of Higher Education*, 93(3), 311-336.
- Sonnert, G., Sadler, P. M., Sadler, S. M., & Bressoud, D. M. (2015). The Impact of Instructor Pedagogy on College Calculus Students' Attitude Toward Mathematics. *International Journal of Mathematics Education for Science and Technology*, 46(3), 370-387.
- Stenta, C., Elliott, R., Matier, M., Scott, J., & R. Adair. (1994). Choosing and leaving science in highly selective institutions. *Research in Higher Education*, 35(5), 513-547.
- Stolle-McAllister, K., Domingo, MRS., & Carrillo, A. (2011). The Meyerhoff way: how the Meyerhoff scholarship program helps black students succeed in the sciences. *Journal of Science Education and Technology*, 20(1), 5-16.

- Summers, M. F., & Hrabowski, FA III. (2014). Preparing minority scientists and engineers (220.1). *The FASEB Journal*, 28(1 Supplement), 220-221.
- Sunstein, C. R. (2013, July 13). Why U.S. students don't major in science. In Bloomberg View. New York City, NY. Retrieved from <http://www.bloombergvview.com/articles/2013-07-17/why-american-students-don-t-major-in-science>.
- Tai, R. H., Qi-Liu, C., Maltese, A. V., & Fan, X. (2006). Career choice. Planning early for careers in science. *Life Science*, 1, 0-2.
- Thomas, R. O. & Bean, J. P. (1988). Student Retention at Liberal Arts Colleges: The Development and Test of a Model. In *annual meeting of the Association for the Study of Higher Education*. St. Louis, MO.
- Tinto, V. (1975). Dropout from higher education: a theoretical synthesis of recent research. *Review of Educational Research*, 45(1), 89-125.
- Tinto, V. (1993). *Leaving College: Rethinking the Causes and Cures of Student Attrition*. The University of Chicago Press: Chicago.
- Tinto, V. (1997). Classrooms as communities: exploring the educational character of student persistence. *The Journal of Higher Education*, 68(6), 599.
- Tinto, V. (2004). Linking learning and leaving. In J. M. Braxton (Ed.) *Reworking the student departure puzzle*. Nashville, TN: Vanderbilt University Press.
- Tinto, V. (2006). Research and practice of student retention: What next? *Journal of College Student Retention*, 8(1), 1-19.
- Toven-Lindsey, B., Levis-Fitzgerald, M., Barber, P. H., & Hasson, T. (2015). Increasing Persistence in Undergraduate Science Majors: A Model for Institutional Support of Underrepresented Students. *CBE-Life Sciences Education*, 14(2), ar12.

- Treisman, U. (1992). Studying students studying calculus: a look at the lives of minority mathematics student in college. *The College Mathematics Journal*, 23(5), 362-372.
- Valentino, L., Moller, S., Stearns, E., & Mickelson, R. (2016). Perceptions of Future Career Family Flexibility as a Deterrent from Majoring in STEM. *Social Currents*, 3(3), 273-292.
- Ware, N.C., Steckler, N.A., & Lesrman, J. (1985). Undergraduate women: who choose a science major? *Journal of Higher Education*, 56(1), 73-84.
- Wesson, C. J., & Derrer-Rendall, N. M. (2011). Self-Beliefs and Student Goal Achievement. *Psychology Teaching Review*, 17(1), 3-12.
- Wilcox, R. R. (2016). *Understanding and applying basic statistical methods using R*. John Wiley & Sons.
- Wolniak, G.C., Mayhew, M.J., and Engberg, M.E. (2012). Learning's weak link to persistence. *The Journal of Higher Education*, (83)6, 795-823.
- Wu, X. & Deshler, J., (in preparation), A Case Study on Career Decision Making Strategies of Calculus I Students
- Wu, X., Deshler, J., & Fuller, E. (in revision). The effects of different versions of a gateway STEM course on student attitudes and beliefs.
- Wu, X., Rambo-Hernandez, K., Fuller, E., & Deshler, J. (under review). The moderation effect of course structures on the relationship between persistence and students' attitudes and beliefs or perceptions of pedagogies
- Xie, Y., Fang, M., & Shauman, K. (2015). STEM Education. *Annual Review of Sociology*, 41, 331-357.
- Yackel, E. and Cobb, P. (1996). Sociomathematical norms, argumentation, and autonomy in mathematics. *Journal for Research in Mathematics Education*, 458-477.

Appendix A

Student Start Term Survey

Default Question Block

You are receiving this survey because you agreed to participate in a research study of A Comparative Study of Calculus at WVU by signing a consent form in your mathematics class. These surveys ask about your demographics information and your attitudes and beliefs about mathematics.

Consent Information Form

Principal Investigator: Dr. Jessica Deshler, Department: Mathematics, Protocol Number: 1501544091

Co-Investigator: Xiangming Wu

Study Title: A Comparative Study of Calculus at WVU

You agreed to participate in this research study by signing a consent form in your mathematics class. This study seeks to improve the understanding of the demographics of students who enroll in Calculus I and to measure the impact of the various characteristics of Calculus I classes that are believed to influence student success. The surveys will generally take less than 15 minutes. Any information about you that is obtained as a result of your participation in this research will be kept as confidential as legally possible. There are no known risks to these surveys. Participation in this study is voluntary. You are free to withdraw your consent to participate in this study at any time. Refusal to participate or withdrawal will not affect your class grade and will involve no penalty to you. This study is being conducted by Dr. Jessica Deshler in the Department of Mathematics at West Virginia University. In the event you have any questions about this research, you should contact Dr. Jessica Deshler at deshler@math.wvu.edu. For information regarding your rights as a research subject, to discuss problems, concerns, or suggestions related to the research, to obtain information or offer input about the research, contact the Office of Research Integrity & Compliance at (304) 293-7073.

1. My placement in calculus was determined by (Mark all that apply):

- ☐ My ACT or SAT score
- ☐ My score on a placement exam
- ☐ My successful completion of prerequisite courses
- ☐ My AP exam score
- ☐ Don't know

2. Did you take the SAT exam?

- ☐ Yes
- ☐ No

3. My SAT scores were:

SAT critical reading

SAT mathematics

4. Did you take the SAT Subject Test in mathematics?

- ☐ Yes
- ☐ No

5. What was your score on the:SAT Subject Test, Mathematics Level
1SAT Subject Test, Mathematics Level
2

10. Please select the most appropriate answer:

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
I am comfortable in using a graphing calculator	☐	☐	☐	☐	☐	☐
I am comfortable in using a computer algebra system (e.g., Maple, MATLAB)	☐	☐	☐	☐	☐	☐

11. My high school mathematics teachers used an electronic response system (such as clickers) to poll students during class

- ☐ Yes
- ☐ No

12. In high school I was allowed to use graphing calculators on exams

- ☐ Always
- ☐ Sometimes
- ☐ Never

13. In high school I was allowed to use calculators that performed symbolic operations on exams (e.g., TI-89, TI-92)

- ☐ Yes
- ☐ No
- ☐ Sometimes

14. Which of the following calculus courses were offered at your high school? (Mark all that apply)

- ☐ Calculus (Non AP)
- ☐ AP Calculus AB
- ☐ AP Calculus BC
- ☐ International Baccalaureate (IB) Calculus
- ☐ Online calculus course
- ☐ Calculus course taught at my high school for which students also received two-year college credit
- ☐ Calculus course taught at a two-year college for which students also received high school credit
- ☐ Calculus course taught at my high school for which students also received four-year college or university credit
- ☐ Calculus course taught at a four-year college or university for which students also received high school credit

15. For each (Non-AP) mathematics course listed below that you took in high school, please indicate the course level, your grade in school when taking the exam, and your final grade (If you did not take a particular course, leave that row blank)

	Course Level	Grade Level in High School	Final Grade
Geometry	<input type="text"/>	<input type="text"/>	<input type="text"/>
Algebra II	<input type="text"/>	<input type="text"/>	<input type="text"/>
Integrated Math	<input type="text"/>	<input type="text"/>	<input type="text"/>
Pre-Calculus	<input type="text"/>	<input type="text"/>	<input type="text"/>
Trigonometry	<input type="text"/>	<input type="text"/>	<input type="text"/>
Statistics (Non AP)	<input type="text"/>	<input type="text"/>	<input type="text"/>
Calculus (Non AP)	<input type="text"/>	<input type="text"/>	<input type="text"/>
Other course taken senior year	<input type="text"/>	<input type="text"/>	<input type="text"/>

16. Did you take any AP Calculus or AP Statistics in high school?

- ☐ Yes
- ☐ No
- ☐ I don't Know

17. For each of the following AP course that you took in high school, please indicate the score you earned on the exam, your grade in school when taking the exam, what grade you earned in the course, and the gender of the teacher

	AP Exam Score (if taken)	Grade Level in High School	Final Grade	Gender of Teacher
Calculus AB	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Calculus BC	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
AP Statistics	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

18. Did you take a calculus course in COLLEGE prior to this one?

- ☐ Yes
- ☐ No

19. Where was your previous college calculus course taken?

- ☐ At this college or university
- ☐ At another 4-year college or university
- ☐ At another 2-year college

20. What was the delivery mode of the calculus course you completed in college prior to this one? (Mark all that apply)

- ☐ Online
- ☐ Through correspondence
- ☐ Face-to-face with an instructor

21. Why are you taking this course again? (Mark all that apply)

- ☐ It did not count toward the credits I need
- ☐ I passed, but I need/want a higher grade (e.g., for my major)
- ☐ I did not pass the course
- ☐ I dropped the class
- ☐ I wanted to get a better grade
- ☐ I wanted to improve my understanding of calculus
- ☐ My college advisor told me to

22. Did you take a pre-calculus course in COLLEGE prior to this course?

- ☐ Yes
- ☐ No

23. Where was your previous college precalculus course taken?

- ☐ At this college or university
- ☐ At another 4-year college or university
- ☐ At another 2-year college

24. What was the delivery mode of the precalculus course you completed in college prior to this one? (Mark all that apply)

- ☐ Online
- ☐ Through correspondence

25. What grade do you expect in this calculus course?

A	B	C	D	F
☐	☐	☐	☐	☐

26. Do you intend to take Calculus II?

- ☐ Yes
- ☐ No
- ☐ I don't know yet

27. How important is a good grade in this course in influencing your decision whether or not to take Calculus II?

- ☐ Very important
- ☐ Important
- ☐ Slightly Important
- ☐ Slightly Unimportant
- ☐ Unimportant
- ☐ Not important at all

28. Is Calculus II required for your major?

- ☐ Yes
- ☐ No
- ☐ I don't know

29. Please select the most appropriate answer.

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
I believe I have the knowledge and abilities to succeed in this course.	☐	☐	☐	☐	☐	☐
I am confident in my mathematical abilities.	☐	☐	☐	☐	☐	☐
I understand the mathematics that I have studied.	☐	☐	☐	☐	☐	☐
I enjoy doing mathematics.	☐	☐	☐	☐	☐	☐

30. If I take another calculus course after this one, it will be because (Mark all that apply)

- ☐ it is required
- ☐ I want to

31. Please select the most appropriate response below:

In the following questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A Not at all certain 1	2	3	B Very certain 4
How certain are you in what you intend to do after college?	☐	☐	☐	☐

32. Please select the most appropriate answer below:

In the following questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A I try hard to figure it out on my own 1	2	3	B I quickly seek help or give up trying 4
When experiencing a difficulty in my math class:	☐	☐	☐	☐

33. Please select the most appropriate answer below:

In the following questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A a natural part of solving the problem 1	2	3	B an indication of my weakness in mathematics 4
For me, making unsuccessful attempts when solving a mathematics problem is:	☐	☐	☐	☐

34. Please select the most appropriate answer below:

In the following questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A solve specific kinds of problems 1	2	3	B make connections and form logical arguments 4
My success in mathematics PRIMARILY relies on my ability to:	☐	☐	☐	☐

35. Please select the most appropriate answer below:

In the following questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A I understand the covered material 1	2	3	B I can do things the way the teacher wants 4
My score on my mathematics exam is a measure of how well	☐	☐	☐	☐

36. Please select the most appropriate answer below:

In the following questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A I would never take another mathematics course 1	2	3	B I would continue to take mathematics 4
If I had a choice,	☐	☐	☐	☐

36. Please select the most appropriate answer below:

In the following questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A I would never take another mathematics course 1	2	3	B I would continue to take mathematics 4
If I had a choice,	☐	☐	☐	☐

37. Please select the most appropriate answer below:

In the following questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A memorize it the way it is presented 1	2	3	B make sense of the material, so that I understand it 4
When studying Calculus I in a textbook or in course materials, I tend to:	☐	☐	☐	☐

38. Please select the most appropriate answer below:

In the following questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A understand underlying mathematical ideas 1	2	3	B find answers to problems 4
When solving mathematics problems, graphing calculators or computers help me to:	☐	☐	☐	☐

39. Please select the most appropriate answer below:

In the following questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A work problems so students know how to do them 1	2	3	B help students learn to reason through problems on their own 4
The primary role of a mathematics instructor is to:	☐	☐	☐	☐

40. Please select the most appropriate answer:

	Strongly Disagree	Disagree	Mildly Disagree	Mildly Agree	Agree	Strongly Agree
Mathematics instructors should show students how mathematics is relevant	☐	☐	☐	☐	☐	☐

41. Please select the most appropriate answer for each of the following.

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
If I am unable to solve a problem within a few minutes, it is an indication of my weakness in mathematics.	☐	☐	☐	☐	☐	☐
Mathematics is about getting exact answers to specific problems.	☐	☐	☐	☐	☐	☐
The process of solving a problem that involves mathematical reasoning is a satisfying experience.	☐	☐	☐	☐	☐	☐

42. Please indicate whether each of the following was born in the U.S.:

	Yes	No
You	☐	☐
Male Parent or Guardian	☐	☐
Female Parent or Guardian	☐	☐

43. What was the highest level of education for your male parent or guardian?

- ☐ Did not finish high school
- ☐ High school
- ☐ Some college
- ☐ Four years of college
- ☐ Graduate school

44. What was the highest level of education for your female parent or guardian?

- ☐ Did not finish high school
- ☐ High school
- ☐ Some college
- ☐ Four years of college
- ☐ Graduate school

45. What was your home zip code at the time you graduated from high school? If you graduated from a high school outside the U.S., enter 00000

46. What is your birth date?

47. Do the following people see you as a person who is good at mathematics?

	Not at all 1	2	3	4	5	Very much 6
Yourself	☐	☐	☐	☐	☐	☐
Parents/Relatives	☐	☐	☐	☐	☐	☐
High school mathematics teacher	☐	☐	☐	☐	☐	☐
Friends	☐	☐	☐	☐	☐	☐

48. What is your gender?

Male
☐

Female
☐

50. Are you of Hispanic origin?

☐ Yes

☐ No

51. Was English the primary language spoken in your household?

- ☐ Yes
- ☐ No

52. What year are you in college?

- ☐ Freshmen
- ☐ Sophomore
- ☐ Junior
- ☐ Senior
- ☐ Graduate Student
- ☐ Other

53. What is your current type of college enrollment?

- ☐ Full-time
- ☐ Part-time

54. To what degree was your home environment supportive of your studying math?

- ☐ Not at all
- ☐ Somewhat
- ☐ Strongly
- ☐ Very Strongly

55. Who encouraged you to take mathematics classes? (Mark all that apply.)

☐ No One	☐ Siblings	☐ Math Teacher
☐ Mother/Female Guardian	☐ Other Relative	☐ Other Teacher
☐ Father/Male Guardian	☐ School Counselor	☐ Coach

56. Where did you attend high school?

- ☐ American school in the United States
- ☐ American school abroad
- ☐ Other (please specify)

57. Approximately how many hours per week do you expect to work at a job this semester/term?

☐ 0	☐ 11-15	☐ 21-30
☐ 1-5	☐ 16-20	☐ More than 30
☐ 6-10		

58. Approximately how many hours per week do you expect to participate in organized extracurricular activities such as sports, college paper, or clubs this semester/term?

- ☐ 0
 ☐ 16-20
☐ 1-5
 ☐ 21-30
☐ 6-10
 ☐ More than 30
☐ 11-15

59. Approximately how many hours per week do you expect to spend preparing for your classes this semester/term (studying, reading, writing, doing homework or lab work, analyzing data, rehearsing, or other academic activities)?

- ☐ 0
 ☐ 16-20
☐ 1-5
 ☐ 21-30
☐ 6-10
 ☐ More than 30
☐ 11-15

60. Which of the following BEST describes your current career goal?

61. Please select the appropriate response for each of the following:

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
I am anticipating difficulty paying for college.	☐	☐	☐	☐	☐	☐
In order to succeed in calculus at a college or university, I must have taken it before.	☐	☐	☐	☐	☐	☐

62. Optional: We may want to contact you to ask follow-up questions about your math related experiences. All communications will be kept in the strictest confidence and your email will NOT be disclosed to any third party. Your email address:

Appendix B

Student End-term Survey

Default Question Block

You are receiving this survey because you agreed to participate in a research study of A Comparative Study of Calculus at WVU by signing a consent form in your mathematics class. These surveys ask about your demographics information and your attitudes and beliefs about mathematics.

Consent Information Form

Principal Investigator: Dr. Jessica Deshler, Department: Mathematics, Protocol Number: 1501544091

Co-Investigator: Xiangming Wu

Study Title: A Comparative Study of Calculus at WVU

You agreed to participate in this research study by signing a consent form in your mathematics class. This study seeks to improve the understanding of the demographics of students who enroll in Calculus I and to measure the impact of the various characteristics of Calculus I classes that are believed to influence student success. The surveys will generally take less than 15 minutes. Any information about you that is obtained as a result of your participation in this research will be kept as confidential as legally possible. There are no known risks to these surveys. Participation in this study is voluntary. You are free to withdraw your consent to participate in this study at any time. Refusal to participate or withdrawal will not affect your class grade and will involve no penalty to you. This study is being conducted by Dr. Jessica Deshler in the Department of Mathematics at West Virginia University. In the event you have any questions about this research, you should contact Dr. Jessica Deshler at deshler@math.wvu.edu. For information regarding your rights as a research subject, to discuss problems, concerns, or suggestions related to the research, to obtain information or offer input about the research, contact the Office of Research Integrity & Compliance at (304) 293-7073.

1. What grade do you expect (or did you receive) in this course?

☐ A ☐ B ☐ C ☐ D ☐ F

2. Is Calculus II required for your intended major?

☐ Yes ☐ No ☐ I'm not sure

3. Do you intend to take Calculus II?

☐ Yes ☐ No ☐ I'm not sure

4. If you do not intend to take Calculus II, check all reasons that apply.

- ☐ I never intended to take Calculus II.
- ☐ I changed my major and now do not need to take Calculus II.
- ☐ My experience in Calculus I made me decide not to take calculus II.
- ☐ I have too many other courses I need to complete
- ☐ To do well in Calculus II, I would need to spend more time and effort than I can afford.
- ☐ My grade in Calculus I was not good enough for me to continue to Calculus II.
- ☐ I do not believe I understand the ideas of Calculus I well enough to take Calculus II.

5. When you started this class, did you intend to take Calculus II?

☐ Yes ☐ No ☐ I wasn't sure

6. Select the appropriate response to each of the following:

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
This course has increased my interest in taking more mathematics.	☐	☐	☐	☐	☐	☐
I am confident in my mathematical abilities.	☐	☐	☐	☐	☐	☐
I am good at computing derivatives and integrals.	☐	☐	☐	☐	☐	☐
I am able to use ideas of calculus (e.g., differentiation, integration) to solve word problems that I have not seen before.	☐	☐	☐	☐	☐	☐
My previous mathematics courses prepared me to succeed in this course.	☐	☐	☐	☐	☐	☐
I enjoy doing mathematics.	☐	☐	☐	☐	☐	☐
Mathematics is about getting exact answers to specific problems.	☐	☐	☐	☐	☐	☐

7. Please select the most appropriate response below.

In this questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A Not at all certain 1	2	3	B Very certain 4
How certain are you in what you intend to do after college?	☐	☐	☐	☐

8. Please select the most appropriate response below.

In this questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A try hard to figure it out on my own 1	2	3	B I quickly seek help or give up trying 4
When experiencing a difficulty in my math class:	☐	☐	☐	☐

9. Please select the most appropriate response below.

In this questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A a natural part of solving the problem 1	2	3	B an indication of my weakness in mathematics 4
For me, making unsuccessful attempts when solving a mathematics problem is:	☐	☐	☐	☐

10. Please select the most appropriate response below.

In this questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A solve specific kinds of problems 1	2	3	B make connections and form logical arguments 4
My success in mathematics PRIMARILY relies on my ability to:	☐	☐	☐	☐

11. Please select the most appropriate response below.

In this questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A I understand the covered material 1	2	3	B I can do things the way the teacher wants 4
My score on my mathematics exam is a measure of how well:	☐	☐	☐	☐

12. Please select the most appropriate response below.

In this questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A I would never take another mathematics course. 1	2	3	B I would continue to take mathematics. 4
If I had a choice:	☐	☐	☐	☐

13. Please select the most appropriate response below.

In this questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A memorize it the way it is presented. 1	2	3	B make sense of the material so I understand it. 4
When studying Calculus I in a textbook or course materials, I tend to:	☐	☐	☐	☐

14. Please select the most appropriate response below.

In this questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A understand underlying mathematical ideas. 1	2	3	B find answers to problems. 4
When solving mathematics problems, graphing calculators or computers help me to:	☐	☐	☐	☐

15. Please select the most appropriate response below.

In this questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A work problems so students know how to do them. 1	2	3	B help students learn to reason through problems on their own. 4
The primary role of a mathematics instructor is to:	☐	☐	☐	☐

16. Please select the most appropriate response below.

In this questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A waited for a student to answer. 1	2	3	B answered the question if no one responded quickly. 4
When my Calculus instructor asked a question addressed to the whole class, s/he:	☐	☐	☐	☐

17. Please select the most appropriate response below.

In this questions, choose number:

1 if you completely agree with option A

2 if you do not completely agree with option A, but agree with option A more than option B

3 if you do not completely agree with option B, but agree with option B more than option A

4 if you completely agree with option B

	A solved the problem for me. 1	2	3	B helped me figure out how to solve the problem. 4
When I asked a question about a problem I was having difficulty solving, my instructor:	☐	☐	☐	☐

18. My Calculus instructor:

[illegible]

19. During class time, how frequently did your instructor:

[illegible]

20. How frequently did your instructor?

[illegible]

21. My Calculus instructor:

[illegible]

22. Indicate how often the following occurred.

	Never	Some class sessions	About half the class sessions	Most class sessions	Every class session
My instructor assigned homework.	☐	☐	☐	☐	☐
Homework was collected (either hard copy or online).	☐	☐	☐	☐	☐
My instructor gave a short quiz.	☐	☐	☐	☐	☐
My instructor used technology.	☐	☐	☐	☐	☐

23. Which of the following technologies did you use during your calculus class? (Check all that apply)

- ☐ None
- ☐ Graphing Calculator
- ☐ Computers
- ☐ Clickers or some other electronic response system

24. How frequently were the following technologies used during class?

[illegible]

36. Did you meet with other students to study or complete homework outside of class?

☐ Yes ☐ No

37. Did you belong to a calculus study group organized by your instructor or department?

☐ Yes ☐ No

38. Does your math department or university provide a walk-in tutor center for mathematics?

☐ Yes ☐ No

39. Approximately how many hours per week did you work at a job this semester/term?

☐ 0
☐ 1-15
☐ 6-10
☐ 11-15
☐ 16-20
☐ 21-30
☐ More than 30

40. Approximately how many hours per week did you participate in organized extracurricular activities such as sports, college paper, or clubs?

☐ 0
☐ 1-15
☐ 6-10
☐ 11-15
☐ 16-20
☐ 21-30
☐ More than 30

41. Approximately how many hours per week did you spend preparing for all classes (studying, reading, writing, doing homework or lab work, analyzing data, or other academic activities) this semester/term?

- ☐ 0
- ☐ 1-15
- ☐ 6-10
- ☐ 11-15
- ☐ 16-20
- ☐ 21-30
- ☐ More than 30

42. Approximately how many hours per week did you spend preparing for calculus (studying, reading, doing homework or lab work) this semester/term?

- ☐ 0
- ☐ 1-15
- ☐ 6-10
- ☐ 11-15
- ☐ 16-20
- ☐ 21-30
- ☐ More than 30

43. What is your home zip code at the time you graduated from high school? If you graduated from a high school outside the U.S., enter 00000

44. What is your birth date?

45. Your email address:

Optional: We may want to contact you to ask follow-up questions about your math-related experiences. All communications will be kept in the strictest of confidence and your email will NOT be disclosed to any third party.

46. Your student ID number:

Optional: We would like to have your student ID to match surveys to the final course grades. This will allow us to correlate course grades with student responses. We assure you that your identity will not be shared with anyone and that your survey responses will be kept in the strictest confidence.

Appendix C

Student Career Survey

Default Question Block

You are receiving this survey because you agreed to participate in a research study of mathematics students' career decisions by signing a consent form in your mathematics class. These surveys ask about career thinking, anxiety and your feeling on inclusion on campus.

Consent Information Form

Principal Investigator: Dr. Jessica Deshler, Department: Mathematics, Protocol Number: 1504657908

Co-Investigator(s): Edgar Fuller, Marjorie Darrah

Study Title: Persistence in STEM of Developmental Mathematics Students

You agreed to participate in this research study by signing a consent form in your mathematics class. The study seeks to understand the career thinking of students in Math Workshop/Math 112/122 and the factors that affect that thinking. The surveys will generally take less than 10 minutes and will be used to plan revisions of future mathematics classes as well as to further understand learning. Any information about you that is obtained as a result of your participation in this research will be kept as confidential as legally possible. There are no known risks to these surveys. Participation in this study is voluntary. You are free to withdraw your consent to participate in this study at any time. Refusal to participate or withdrawal will not affect your class grade and will involve no penalty to you. This study is being conducted by Dr. Jessica Deshler in the Department of Mathematics at West Virginia University. In the event you have any questions about this research, you should contact Dr. Jessica Deshler at deshler@math.wvu.edu. For information regarding your rights as a research subject, to discuss problems, concerns, or suggestions related to the research, to obtain information or offer input about the research, contact the Office of Research Integrity & Compliance at (304) 293-7073.

I willingly agree to be in the study

☐ Yes

☐ No

Block 1

Career Decision Making Survey

This survey seeks to understand your current thinking about you major and your future career.

How did you decide to come to college at WVU?

What is your current major?

How did you come to decide on your current major?

What job(s) would you like to have after completing school?

- a.
- b.
- c.
- d.

Block 2

Career Decision Making Survey

This survey seeks to understand your current thinking about your major and your future career.

What seems attractive about your current major or career goals?

Did you consider other careers before selecting your current career/major?

- ☐ Yes
- ☐ No

If yes, what other careers did you consider before selecting your current career/major?

- a.
- b.

c.

d.

At what age did you consider these other careers?

At what age did you select your current career?

Block 3

Career Decision Making Survey

This survey seeks to understand your current thinking about you major and your future career.

Here are a number of characteristics that may or may not apply to you. Please indicate the extent to which you agree or disagree with each statement.

	Disagree Strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree Strongly
I had difficulty choosing a college major and a future career path.	☐	☐	☐	☐	☐
I feel good about my current position with respect to my major.	☐	☐	☐	☐	☐
Most parents have plans for their children, things they'd like them to do or go into. My parents have plans like that for me.	☐	☐	☐	☐	☐
My parents feel good about what I'm doing now.	☐	☐	☐	☐	☐
I would be willing to change my current plans if something better came along.	☐	☐	☐	☐	☐
I see my occupation as being important to me in my life.	☐	☐	☐	☐	☐
My family's opinion was very important in helping me choose my current major.	☐	☐	☐	☐	☐
If my family were supportive, I would be likely to change my major.	☐	☐	☐	☐	☐

Block 4

Career Decision Making Survey

This survey seeks to understand your current thinking about you major and your future career.

Are you considering changing your major?

- ☐ Yes
☐ No

If yes, what other majors are you considering? (List the serious contenders)

- a.
 b.
 c.

If you are considering changing majors, which of the following reasons are involved? (Select all that are important)

- ☐ I don't find my current major very interesting anymore.
☐ I found another major that is more interesting.
☐ I found another major that better fits my talents.
☐ My current major really wasn't what I expected.
☐ I just don't feel I belong when I am with other students in my major.
☐ My current department does not seem interested in me.
☐ I am not sure I can be successful in my current major.

Here are a number of characteristics that may or may not apply to you. Please indicate the extent to which you agree or disagree with each statement.

	Disagree Strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree Strongly
It is likely that my current major is the major that I will graduate with.	☐	☐	☐	☐	☐
I think it is likely that I will graduate from WVU or another university.	☐	☐	☐	☐	☐

Have you ever taken a class at WVU that was not required so you could find out more about an alternate career/major?

- ☐ Yes
☐ No

Have you attended a club meeting, departmental event, or informational meeting to find out more about alternate careers?

- ☐ Yes
- ☐ No

Select any of the following factors that may keep you from graduating.

- ☐ Financial or scholarship problems.
- ☐ College just doesn't seem right for me now.
- ☐ Family issues.
- ☐ Classes just are not going very well.

Please rate your investigation of your planned profession.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I have thoroughly investigated my planned profession.	☐	☐	☐	☐	☐

If you have investigated your planned profession, please indicate in which areas you have spent time looking for information. (select all that apply)

- ☐ I have family members or friends of family in my planned occupation that have given me excellent advice.
- ☐ I have worked (volunteered, interned) for companies that do what I want to do.
- ☐ I have attended school meetings with presentations from members of the profession.
- ☐ I have investigated the profession thoroughly online.
- ☐ Other

Block 7

Without your consent to be in this study you cannot take part in this survey. Thank you for your interest.