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Examining the Impact of Introductory Mathematics Courses on Undergraduate Students' Desire to Pursue a STEM Major

Sydney Hunt, Duke University

Sydney Hunt is a Reginaldo Howard Memorial Scholar at Duke University (Class of 2023). She is majoring in Electrical/Computer Engineering and Computer Science with a concentration in Artificial Intelligence and Machine Learning. She is also minoring in Gender, Sexuality, and Feminist Studies. Sydney plans to pursue a Ph.D. in Electrical/Biomedical Engineering post-graduation while continuing to be heavily involved in organizations dedicated to mentoring and empowering the next generation. Through her involvement in the Improving Girls' Math Identity Through Problem Solving and Mentorship Bass Connections Research Team at Duke University, she became particularly interested in reducing student dependence upon supplemental organizations to compensate for unsupportive STEM classroom environments.

Shaundra Bryant Daily, Duke University

Shaundra B. Daily is a professor of practice in Electrical and Computer Engineering & Computer Science at Duke University and Levitan Faculty Fellow, Special Assistant to the Vice Provosts. Prior to joining Duke, she was an associate professor with tenure at the University of Florida in the Department of Computer & Information Science & Engineering. She also served as an associate professor and interim co-chair in the School of Computing at Clemson University. Her research focuses on the design, implementation, and evaluation of technologies, programs, and curricula to support diversity, equity, and inclusion in STEM fields. Currently, through this work, she is the Backbone Director for the Alliance for Identity-Inclusive Computing Education as well as Education and Workforce Director for the Athena AI Institute. Having garnered over $40M in funding from public and private sources to support her collaborative research activities, Daily's work has been featured in USA Today, Forbes, National Public Radio, and the Chicago Tribune. Daily earned her B.S. and M.S. in Electrical Engineering from the Florida Agricultural and Mechanical University – Florida State University College of Engineering, and an S.M. and Ph.D. from the MIT Media Lab.

Shira Viel
Dr. Karis Boyd-Sinkler, Duke University

Karis Boyd-Sinkler, PhD is the Director of Diversity, Equity, & Inclusion and Adjunct Assistant Professor at Duke University's Pratt School of Engineering. She plays a key role in providing strategies to strengthen Pratt's efforts to create and sustain an equitable environment for all members of the Pratt Community including students, staff, faculty, and alumni. She has over 7 years of experience leading multiple mentoring, outreach, and professional development programs focused on the recruitment and retention of engineering students at all levels, especially students from Black and Hispanic/Latino populations. Dr. Boyd-Sinkler has a B.S. in Engineering Science from the University of Virginia and a M.Eng in Industrial and Systems Engineering and a Ph.D. in Engineering Education from Virginia Tech.

Examining the impact of introductory mathematics on student desire to pursue a STEM degree

1. Introduction

In 2019, women represented only 27% of science, technology, engineering, and mathematics (STEM) workers [5]. Many reasons have been given for this underrepresentation of women including a lack of role models, implicit biases discouraging participation, limited exposure to STEM fields, and stereotype threat; however, the impact of introductory mathematics on students' desire to pursue an undergraduate STEM degree remains an area of interest for many educators and researchers. The significance of mathematics in a student's intellectual growth is immense, as it enhances their analytical thinking, problem-solving proficiency, and logical reasoning. Additionally, it creates a strong base for pursuing STEM fields, which can lead to profitable career prospects. [23] showed that mathematics courses could be the turning point for women in deciding not to choose STEM careers, which supports the finding that "if women persisted in STEM at the same rate as men starting in Calculus I, the number of women entering the STEM workforce would increase by 75%" [8].

This paper aims to answer the following three research questions: How is a student's desire to pursue a STEM degree affected by the style of their Calculus I course? What is the relationship between the style of Calculus I courses taken at the undergraduate level and students' overall attitudes and perceptions toward mathematics? How do the answers to the previous two research questions vary by gender? More specifically, this research investigated how class format (online due to COVID-19 vs in-person), instruction style (large lecture vs small classroom), and assessment methods (letter vs satisfactory grading) collectively impact students' desired undergraduate major(s) while enrolled in an introductory mathematics course (Calculus I) taken at a four-year institution.

Quantitative experimental data were collected from N=712 undergraduate Calculus I students at a private, highly-selective U.S. university during the fall 2020, fall 2021, and spring 2022 semesters. Students took the Mathematics Attitudes and Perceptions Survey (MAPS) [6] and/or the Short Form Test Anxiety Inventory (TAI-5) Questionnaire [26] at both the start and end of the semester. Of the N=712 responses, N=209 were matched responses (students completed at least one question on both the pre- and post-survey). These matched survey data and demographic information (gender) have been used to evaluate the change in student attitudes towards mathematics, perception towards mathematics, and desired undergraduate major based on their course participation. The results provide insight into the impact of introductory mathematics on student motivation and engagement in STEM and can provide recommendations for how introductory mathematics courses can be designed and taught to increase student interest in STEM fields.

2. Related Work

2.1 Student Attitudes and Perceptions Toward Mathematics

Previous research on the influence of introductory mathematics often highlights the relationship between student mathematical skills and overall academic performance. Several studies have demonstrated that a strong foundation in mathematics, particularly during the early years of education, is a key predictor of students' future academic achievement and success in higher education [2,9]. Additionally, research has found that students who struggle with introductory mathematics are more likely to struggle in other subjects, particularly those in STEM fields. Yet, the ramifications of challenges in mathematics go beyond academic performance, as it can lead to a negative attitude towards the subject, hindering one's confidence, motivation to learn, and sense of belonging [22]. As a result, researchers have emphasized the importance of effective mathematics instruction, as well as early identification and support for students who encounter difficulties in the subject [27,4].

2.2 Class Performance

The studies that focused on the relationship between math identity and achievement involved the investigation of how positive or negative math identities may impact students' performance in mathematics courses. [10] examined the correlation between students' understanding of intelligence and their math performance. It was revealed that students who perceived intelligence as an inherent trait were more likely to have lower math performance in comparison to those who believed that intelligence can be cultivated through effort and learning. The findings suggest that the development of a student's math identity is influenced by their mindset regarding intelligence, and encouraging a growth mindset can potentially enhance math performance.

Similarly, [17] investigated the correlation between math self-concept and math achievement among high school students. The study demonstrated that students with a positive perception of their math abilities had better math performance than those with a negative self-concept. Furthermore, the research indicated that the relationship between math self-concept and math achievement was more pronounced for women students than for men students. The results indicate that addressing negative math self-concepts may potentially enhance math performance, particularly among women students, and that math self-concept plays a crucial role in determining students' math achievement.

2.3 Impact of One's Environment

Researchers have also investigated how societal stereotypes about gender and math impact girls' math identity development. [25] developed a theory of identity that centers on stereotype threat. According to this theory, when individuals are aware of negative stereotypes that exist about their social group, they may experience anxiety and perform poorly on tasks related to those stereotypes. Steele argued that this occurs because people's performance is influenced by their perceptions of the stereotypes, which can activate negative thoughts and emotions that hinder their abilities. This theory has significant implications for understanding how stereotypes affect academic achievement and other areas of life and for developing interventions to help people overcome stereotype threats and achieve their full potential.

[3] further emphasized the importance of supportive classroom environments by examining how math identity develops over time and the factors that influence this development. The study revealed that students' math identities are shaped by their experiences in math classes. Negative experiences lead to weaker math identities, while positive experiences lead to stronger math

identities. The study emphasized the significance of cultivating a positive learning atmosphere that encourages collaboration, engagement, and a growth mindset to support the development of positive math identities.

[18] also found that students' math identities were positively related to their achievement in Calculus I courses. They conducted a study on the relationship between math identities and academic achievement in Calculus I courses. The study found that students who had a strong positive math identity performed better academically than those who did not. Furthermore, the study highlighted that receiving support from family and friends, as well as intrinsic motivation, were factors that contributed to a positive math identity and academic performance. The results of this study suggest the importance of fostering a positive math identity in students, along with providing support and motivation to help them excel in math courses.

2.4 Confidence

In addition to empirical research, scholars have also developed theoretical models to explain the development and maintenance of math identity. [7] proposed the expectancy-value theory, which suggests that students' beliefs about their abilities and the value they place on a particular subject influence their motivation and subsequent achievement in that subject. This theory implies that students who believe they have high ability in a subject and see the value in that subject are more likely to be motivated to perform well in that subject. Conversely, students who believe they have a low ability or do not see the value in a subject are less likely to be motivated to perform well in that subject. [28] supported this theory through the observation that students who placed a high value on mathematics and had confidence in their abilities to succeed in the subject were more inclined to take advanced math courses and earn higher grades. [11] demonstrated that enhancing students' beliefs about the significance of mathematics and their self-efficacy in the subject contributed to greater motivation and achievement in math.

Nevertheless, so much more can be learned about how math identity develops and how educators can support the development of a positive math identity for all students. [14] examined how academic motivation influences high school students' academic achievement. They surveyed 1,100 high school students and measured their intrinsic, identified, external, and amotivational tendencies, along with their GPA and standardized test scores over two years. The results showed that students who were intrinsically motivated or motivated by personal values and interests outperformed those who were motivated by external rewards or pressure, or lacked motivation. The study emphasized the significance of promoting intrinsic motivation and identified regulation in students to achieve better academic outcomes.

2.5 Gender

Additional research was conducted to observe how society influenced math identity differences by gender. [19,16] examined the relationship between societal stereotypes about gender and math. They found that these stereotypes significantly and negatively impact math identity development and achievement, especially for girls. The research revealed that girls had a weaker math identity resulting from them often holding negative beliefs about their math abilities due to gender stereotypes. The study also found that teachers' beliefs about their students' math abilities can influence their students’ math identity, again, particularly for girls. The authors suggest that interventions to promote a positive math identity for girls should focus on challenging gender stereotypes and supporting teachers in creating equitable and inclusive classroom environments.

Furthermore, research has highlighted the importance of addressing implicit biases among educators, as these biases may impact their expectations of girls’ math ability. [13] highlighted the importance of addressing implicit biases in educators, which can have an impact on their expectations of girls' math ability. If educators hold negative stereotypes or biases, they may have lower expectations of girls' math skills, which can lead to gender inequity in the classroom. Therefore, it is necessary to address these biases among educators to promote equity and inclusion in the classroom, which can benefit the academic success of all students, regardless of gender. Research has emphasized the need to address implicit biases among educators to improve the educational opportunities and achievements of women students in math.

In addition to empirical research, scholars have also proposed theoretical models to explain girls’ math identity development. [15] proposed the social cognitive career theory, which emphasizes the significance of individual and environmental factors in career choice and development. The theory suggests that a person's interests, abilities, and self-efficacy beliefs are vital in shaping their career aspirations and goals. Furthermore, the theory recognizes that social and environmental factors, such as family and cultural values, role models, and opportunities, impact career choices. The social cognitive career theory has broad implications for career counseling and development interventions. It highlights the importance of promoting self-efficacy beliefs and creating supportive environments for career exploration and decision-making.

2.6 Time

[1] investigated the factors that influence the development of students' calculus skills in Calculus I courses using a qualitative case study approach. They found that various factors affect the development of calculus skills, including instructor pedagogy, course structure, student motivation, and study habits, and prior mathematical preparation. Instructors who prioritize conceptual understanding and active learning strategies have a positive impact on student learning. However, challenges such as insufficient prerequisite knowledge and poor study habits can hinder students' calculus development. The authors recommend a comprehensive approach that includes individual student support and broader curricular and instructional changes to address these challenges. Overall, the study underscores the importance of ongoing efforts to improve calculus instruction and support student learning.

2.7 Student Engagement

More recently, scholars have focused on how math identity is related to student engagement and retention in Calculus I courses. [24] investigated the connection between students' math identity and their pursuit of STEM degrees and careers, focusing on those taking Calculus I courses. Through a survey, they found that students who developed a positive math identity, characterized by a sense of belonging in math and confidence in their ability to learn math, were more likely to continue pursuing STEM degrees and careers. Additionally, these students showed higher levels of engagement and motivation in their calculus course and were more likely to seek help when facing challenges. Encouragement and support from instructors, peers, and family members were also found to contribute to a positive math identity. In contrast, negative experiences such as stereotype threat and math anxiety were linked to lower levels of math identity and decreased interest in STEM fields. The authors recommend creating supportive learning environments and opportunities for students to develop their math skills and confidence to promote a positive math identity and encourage success in STEM fields.

2.8 Self-Perception

In the context of theoretical models, various explanations have been proposed to explain the development and maintenance of math identity in Calculus I courses. [12] investigated the relationship between students' math identity development in Calculus I courses and their basic psychological needs, using self-determination theory as a framework. The study found that students' need for autonomy, competence, and relatedness were critical factors that shaped their math identity. In particular, students who perceived themselves as having a high level of autonomy, competence, and relatedness were more likely to develop a positive math identity. Autonomy was found to be the most crucial predictor of math identity, followed by relatedness and competence. Additionally, the study highlighted that students' experiences in Calculus I courses, including the quality of instruction, the teaching style of instructors, and the support from peers, had a significant impact on their basic psychological needs and math identity development. Therefore, the study emphasizes the significance of fostering a supportive learning environment that promotes autonomy, competence, and relatedness in positively influencing math identity development.

2.9 COVID-19

[21] examines the impact of the COVID-19 pandemic on the identities of Japanese tenth-grade students in mathematics as they transitioned from classroom to remote learning. The study highlights the challenges faced by students in maintaining their mathematical identity and obtaining positive social feedback, leading to an overlooked equity issue where rich learning resources were unavailable due to a lack of necessary knowledge and positive self-identification. The study suggests the need to continue supporting students in constructing their identities during unexpected events. Although the findings of this study are informative for the current study, it is important to note that the students were not based in U.S. classrooms and the sample size was small, consisting of only two participants. Therefore, caution should be exercised when generalizing the results..

[9] investigated whether underrepresented (UR) students were disproportionately weeded out of STEM majors due to poor performance in core introductory courses required for STEM degrees. Through the use of a multi-institutional database, this study found that underrepresented (UR) students are more likely to fail to obtain a STEM degree if they perform poorly in these courses, even after controlling for academic preparation and intent to obtain a STEM degree. Predicted probabilities of STEM degree attainment for students of different demographics reveal a significant disparity between UR women students and STEM-intending white men students. Overall, the study highlights the dire situation in higher education and the need to diversify STEM by critically examining institutional structures at all educational levels.

2.10 Summary

Overall, the previous research on math identity in Calculus I has demonstrated its importance for students' academic success and their engagement and retention in STEM fields. However, more research is needed to understand the complex factors that contribute to the development of math identity in Calculus I courses and to identify effective interventions to promote positive math identities among students. In the context of gender, the previous research on girls' math identity has highlighted the importance of creating supportive environments that foster positive math identities among girls. While progress has been made, there is still a need for further research to better understand the complex factors that contribute to girls' math identity development and to develop effective interventions to promote positive math identities among girls. This paper focuses specifically on Calculus I because some of the earliest research on math identity has been focused on the relationship between math identity and achievement in Calculus I courses.

3. Methods

Table 1 describes the style of the Calculus I courses analyzed in this paper. Students filled out the MAPS and Demographics questionnaire during all three semesters. Students filled out the TAI-5 questionnaire during the fall 2021 and spring 2022 semesters.

This data was distributed to the author by a professor at the four-year institution where this study was conducted. The professor taught all the Calculus I courses used in this paper.

Table 1: Course Offerings

Semester and Year	Matched Responses	Class Type	Grading Type	# of Professor(s)	Delivery
Fall 2020	N=31	Remote	Mandatory S/U	1	Asynchronous lectures Synchronous labs Medium classroom setting
Fall 2021	N=120	In-person	Letter	1	Synchronous lectures Synchronous labs Large lecture setting
Spring 2022	N=68	Hybrid	Letter	2	Hybrid lectures Hybrid labs Small classroom setting

3.1 Participants

Data were collected from N=712 undergraduate Calculus I students at a private, highly-selective U.S. university during the fall 2020, fall 2021, and spring 2022 semesters. Of the N=712 responses, N=209 were matched responses (a student completed at least one question on both the pre- and post-survey). Since this paper is examining the impact of the Calculus I course, only matched responses were analyzed. The distribution of N=209 matched responses was N=28, N=120, and N=61 students for fall 2020, fall 2021, and spring 2022 respectively (Table 2).

3.2 Procedures

The fall 2020 course was taught fully remotely to adhere to the safety constraints of the COVID-19 pandemic. All lectures were recorded by one professor and delivered asynchronously. Students then remotely attended twice-weekly 75-minute synchronous lab sessions, in 8 sections of around 28 students each. Grading was done on a mandatory Satisfactory/Unsatisfactory basis, with a variation on mastery grading wherein students had a resubmission or retake opportunities for all assessments. The fall 2021 course was taught in person, as the constraints of the COVID-19 pandemic were at that point lifted. One professor taught two sections in a large lecture setting with a letter grading method of assessment. The spring 2022 course was taught in a hybrid classroom environment due to the reinstated COVID-19 safety constraints. Two professors each taught two sections of the course in a small classroom setting with a letter grading method of assessment. Each professor covered the same content in the same order and had the same homework, exams, lecture slides, and course policies. After the initial two weeks of the semester when all courses taught at the four-year were remote due to a rise in COVID-19 cases, the first professor taught the course in-person (with casting on Zoom) for the remainder of the semester. The second professor switched to teaching lectures remotely about halfway through the semester, with their lab sections continuing to meet in person.

3.3 Measures

Students took a single survey that consisted of 36 or 41 total questions at the start and end of the semester. This survey included all 32 Mathematics Attitudes and Perceptions Survey (MAPS) questions (Appendix Tables 2,3), 5 Short Form Test Anxiety Inventory (TAI-5) questions (Appendix Table 4), and/or 4 demographic questions (Appendix Table 5). In the fall 2020 semester, MAPS and Demographics responses were collected. In the fall 2021 and spring 2022 semesters, MAPS, Demographics, and TAI-5 responses were collected.

MAPS is designed to assess students' attitudes, beliefs, and perceptions about mathematics. It aims to understand how students perceive mathematics and to identify any negative attitudes or misconceptions that may be hindering their learning. MAPS covers a range of topics related to students' attitudes and perceptions about mathematics, including their confidence in their ability to do math, their beliefs about the usefulness and relevance of math, their perceptions of math as a difficult or easy subject, and their experiences with math teachers and peers. Respondents rate the frequency and intensity of each symptom on a 5-point Likert scale, ranging from "Strongly Agree" to "Strongly Disagree".

TAI-5 is a psychological assessment tool designed to measure the level of test anxiety in individuals. The purpose of this inventory is to identify individuals who experience anxiety specifically related to test-taking and to provide a standardized way to measure the severity of their test anxiety. The TAI-5 consists of items that assess the cognitive, emotional, and behavioral symptoms of test anxiety, such as worry, fear of failure, physical tension, and interference with performance. Respondents rate the frequency and intensity of each symptom on a 4-point Likert scale, ranging from "Almost Never" to "Almost Always".

3.4 Analysis

For the fall 2020 semester, N=28 MAPS and Demographics matched responses were collected. During the fall 2021 and spring 2022 semesters, N=120 and N=61 MAPS, Demographics, and TAI-5 matched responses were collected, respectively. Across all semesters, each matched response had every MAPS and TAI-5 question answered. However, not all matched responses included a response to the demographic question.

Box and whisker plots were created in order to analyze any differences between the pre- and post-semester MAPS and/or TAI-5 ratings. These results were plotted by MAPS category, with separate plots for the TAI-5 questionnaire. The means, represented on these plots by a black 'x', were found by averaging the ratings by MAPS and/or TAI-5 category. The median MAPS and TAI-5 category values are represented by a blue line. The shaded purple region represents the interquartile range (25th to 75th percentile). The horizontal black lines at the end of each whisker represent the minimum and maximum values. Outliers are represented by purple circles. The following four demographic questions were asked: In what math course are you currently enrolled?; How would you describe yourself? (Select all that apply.); How would you describe yourself? (Select all that apply.); If known, what is your intended (or declared) major? Out of the four questions, only two questions were used in the analysis of this data (gender and desired major) in order to retain student privacy.

4. Results

4.1 MAPS Results

The mean rating values for the MAPS questions related to a growth mindset in Calculus I remained approximately the same when comparing the pre and post-ratings across all course offerings. While the interquartile range of response ratings was equal across all semesters, students had higher mean MAPS ratings during fall 2020 in comparison to fall 2021 and spring 2022. The mean fall 2021 and spring 2022 ratings related to growth mindset were approximately equal.

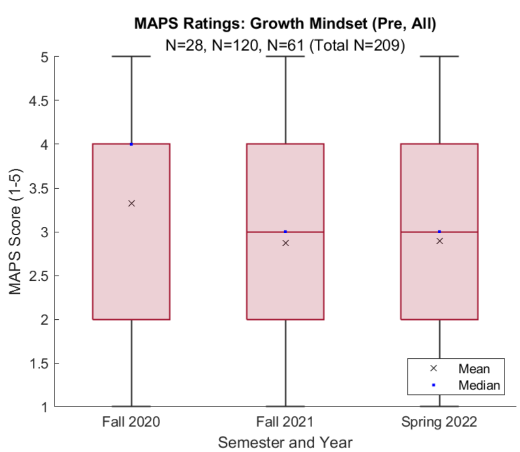

Figure 1: Growth Mindset (Pre, All)

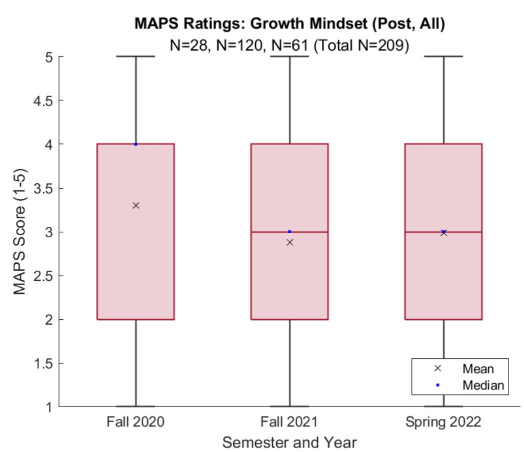

Figure 2: Growth Mindset (Post, All)

Next, the mean rating values for the MAPS questions related to the real-world applications of Calculus I remained approximately the same when comparing the pre and post-ratings across all course offerings. The interquartile range of response ratings remained consistent for fall 2020 and fall 2021, and increased for spring 2022. Based on the mean ratings in this MAPS category, students appeared to perceive Calculus I to have fewer real-world applications during fall 2020 in comparison to fall 2021 and spring 2022. The mean fall 2021 and spring 2022 MAPS ratings related to real-world were approximately equal.

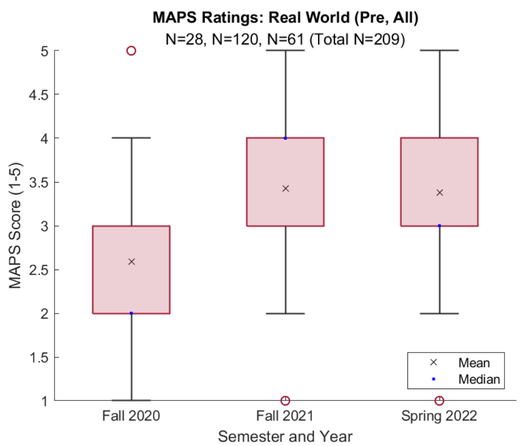

Figure 3: Real World (Pre, All)

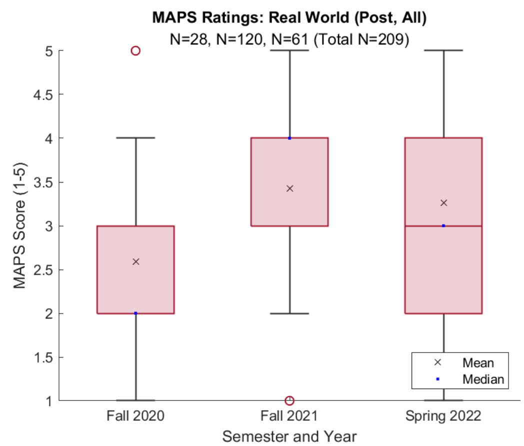

Figure 4: Real World (Post, All)

With respect to confidence, the mean rating values for the MAPS questions related to student confidence in Calculus I remained approximately the same when comparing the pre and post-ratings across all course offerings. The interquartile range of response ratings remained consistent for fall 2020 and fall 2021, and decreased for spring 2022. Based on the mean ratings in this MAPS category, students appeared to be more confident in their mathematics skills during spring 2022 in comparison to fall 2020 and fall 2021. The mean fall 2020 and fall 2021 MAPS ratings related to confidence were approximately equal.

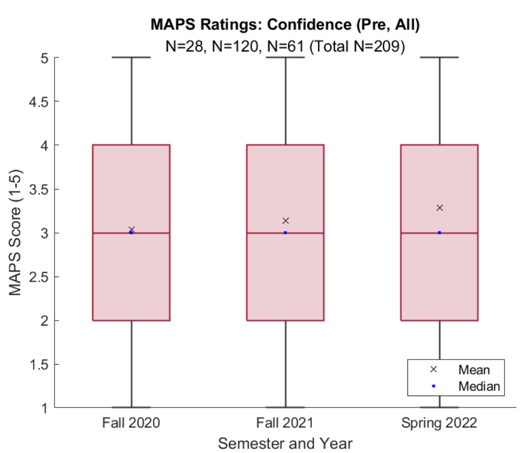

Figure 5: Confidence (Pre, All)

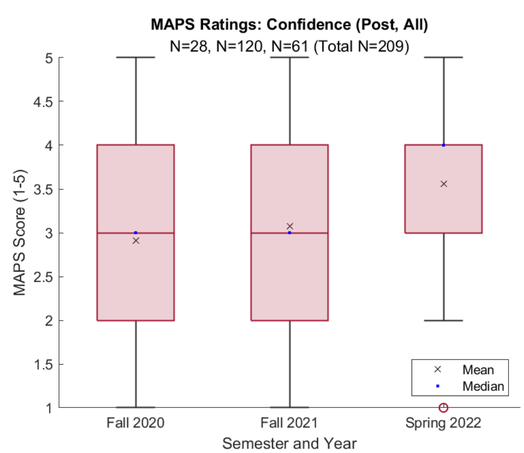

Figure 6: Confidence (Post, All)

Next, the mean rating values for the MAPS questions related to student interest in Calculus I remained approximately consistent between pre- and post-ratings during fall 2020, and increased for both fall 2021 and spring 2022. The interquartile range of response ratings remained consistent across all semesters. Based on the mean ratings in this MAPS category, students appeared to be more interested in mathematics skills during fall 2021 and spring 2022 in comparison to fall 2020. The mean fall 2021 and spring 2022 MAPS ratings related to interest were approximately equal.

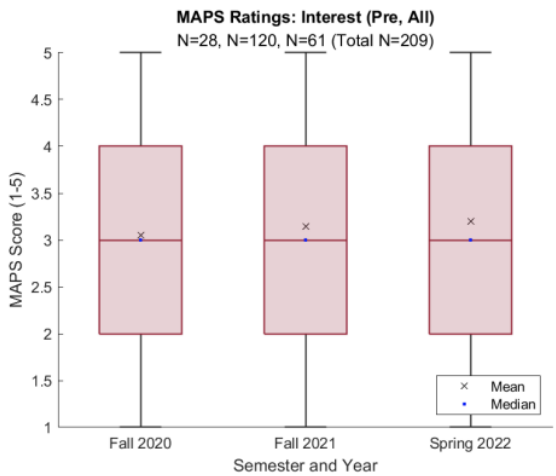

Figure 7: Interest (Pre, All)

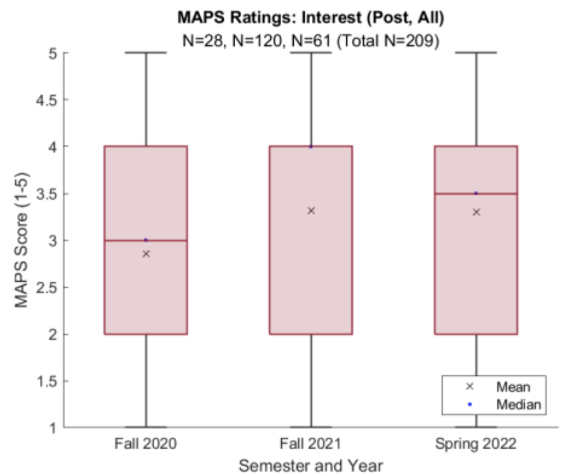

Figure 8: Interest (Post, All)

For persistence, the mean rating values for the MAPS questions related to student persistence in Calculus I remained approximately consistent between pre- and post-ratings across all course offerings. The interquartile range of response ratings decreased during fall 2020 and remained equal for fall 2021 and spring 2022. Based on the mean ratings in this MAPS category, students had the most persistence during fall 2020, and the least persistence during fall 2021.

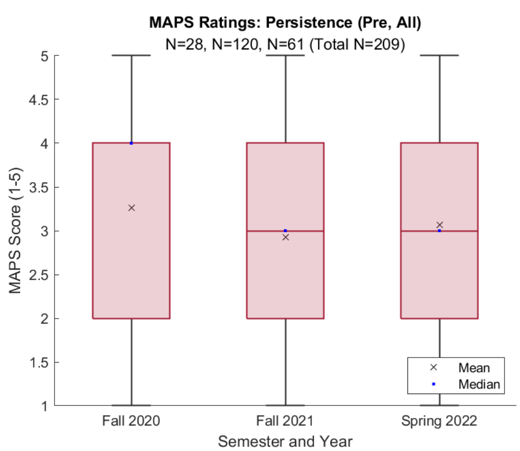

Figure 9: Persistence (Pre, All)

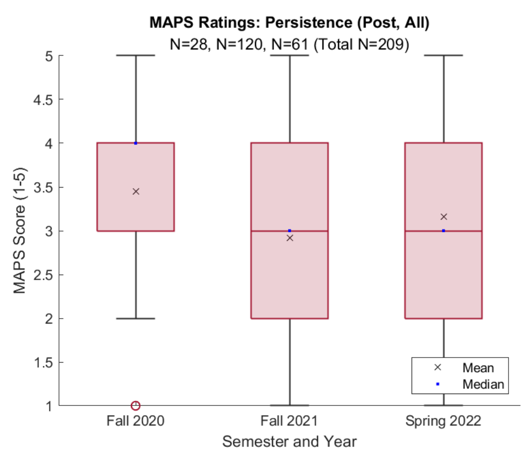

Figure 10: Persistence (Post, All)

The mean rating values for the MAPS questions related to student sense-making in Calculus I remained approximately consistent between pre- and post-ratings across all course offerings. The interquartile range of response ratings was equal across all semesters. Based on the mean ratings in this MAPS category, students perceived Calculus I to make the most sense during fall 2020 in comparison to fall 2021 and spring 2022. The mean fall 2021 and spring 2022 ratings were approximately equal.

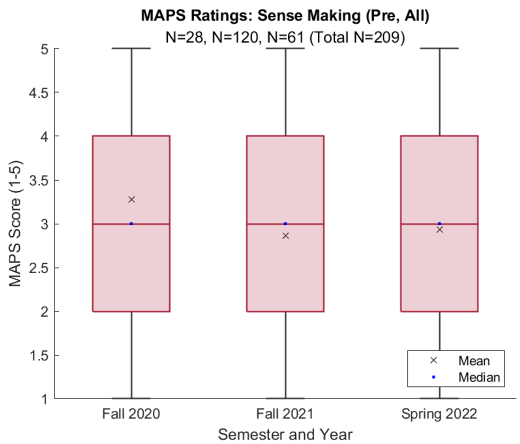

Figure 11: Sense-Making (Pre, All)

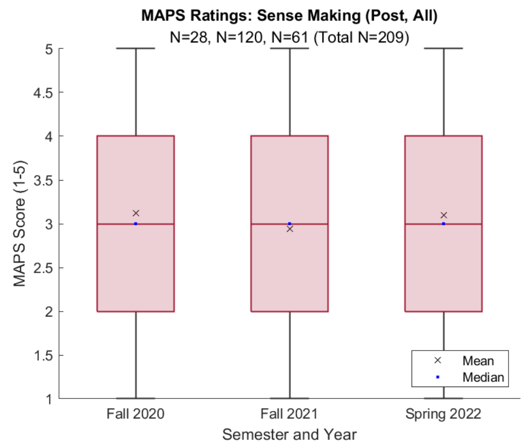

Figure 12: Sense-Making (Post, All)

The mean rating values for the MAPS questions related to student ability to find answers in Calculus I remained approximately consistent between pre- and post-ratings across all course offerings. The interquartile range of response ratings remained consistent during fall 2020 and fall 2021, and increased during spring 2022. Based on the mean ratings in this MAPS category, students appeared to be able to find more answers during exams during fall 2020 than fall 2021 and spring 2022. The mean fall 2021 and spring 2022 ratings were approximately equal.

4.2 TAI-5

The mean rating values for the TAI-5 questionnaire remained approximately consistent between pre- and post-ratings for spring 2022, while the mean fall 2021 rating decreased. The interquartile range of response ratings remained consistent during both semesters but became smaller for fall 2021. Based on the mean rating values, students appeared to have more anxiety about mathematics and test-taking during spring 2022 than fall 2021.

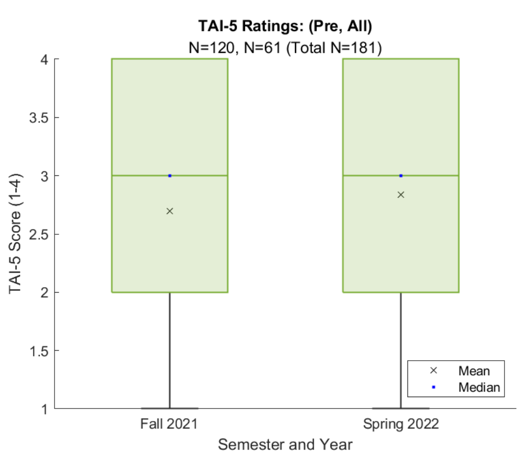

Figure 13: TAI-5 (Pre, All)

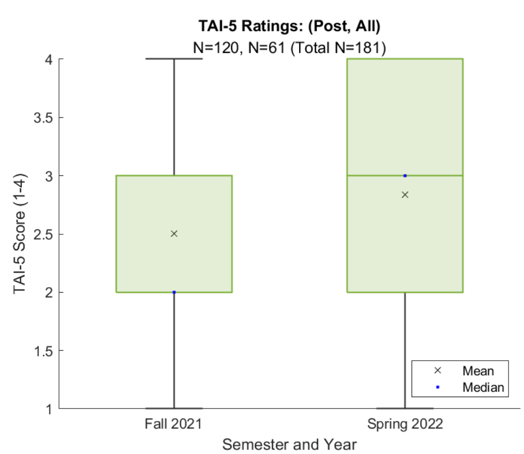

Figure 14: TAI-5 (Post, All)

4.3 Fall 2020

Overall, the MAPS category means had little variation between pre and post-responses for all students as well as men and women grouped separately. The MAPS category with the lowest mean rating value was Real World, suggesting that during fall 2020 students as a whole saw little real-world applications of Calculus I, although women (2.7500 pre, 2.6563 post) saw more value than men (2.4000 pre, 2.6000 post).

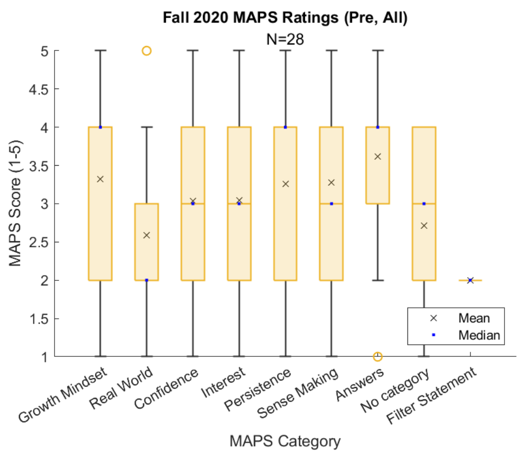

Figure 15: MAPS (Pre, All)

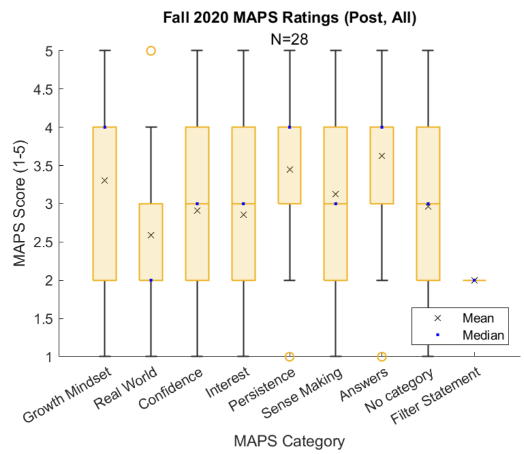

Figure 16: MAPS (Post, All)

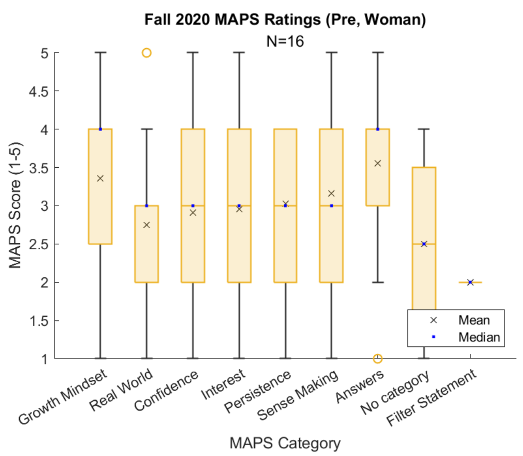

Figure 17: MAPS (Pre, Women)

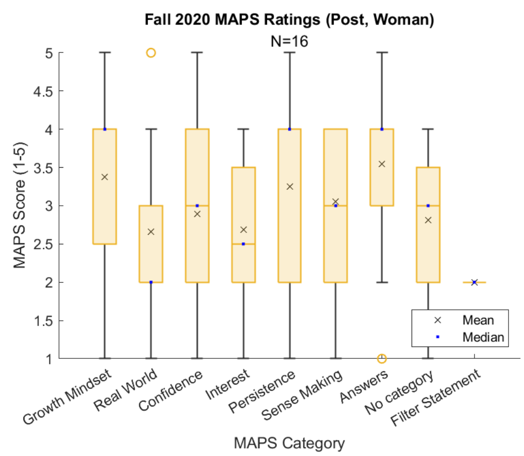

Figure 18: MAPS (Post, Women)

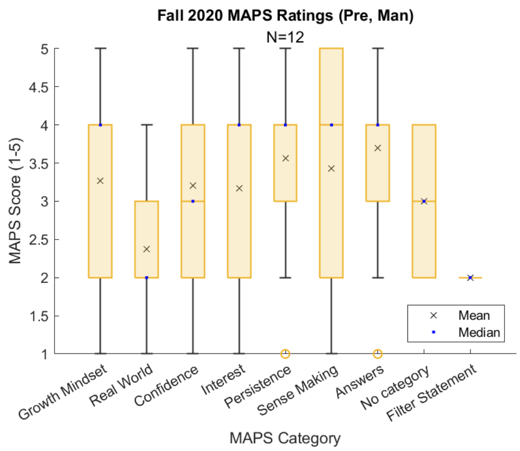

Figure 19: MAPS (Pre, Men)

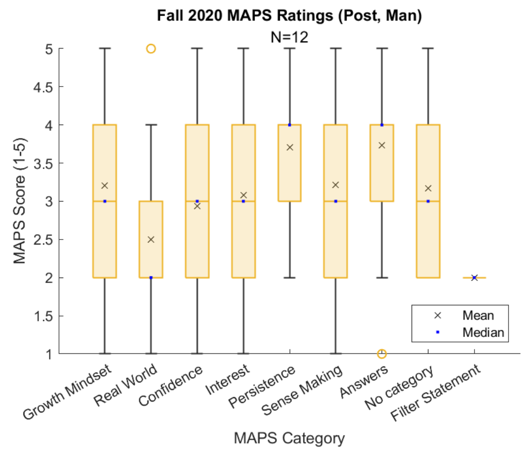

Figure 20: MAPS (Post, Men)

4.4 Fall 2021 (All Students)

Overall, the MAPS category means had little variation between pre and post-responses. The MAPS category with the lowest mean rating value was Answers (2.4333 pre, 2.4601 post), suggesting that during fall 2021 students appeared to find more value in applying than memorizing mathematical formulas/concepts, although women appeared to find more value (2.3667 pre, 2.4080 post) in applying than memorizing mathematical formulas/concepts than men (2.5272 pre, 2.5271 post).

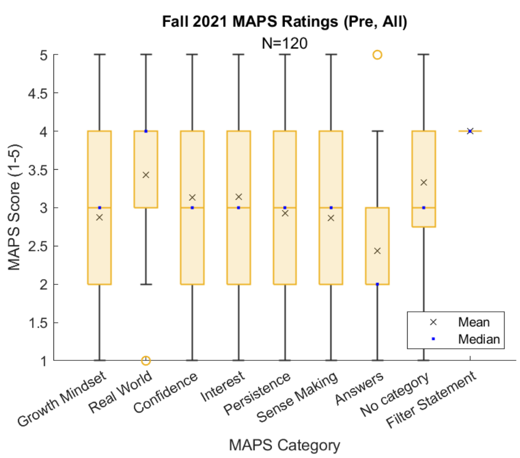

Figure 21: MAPS (Pre, All)

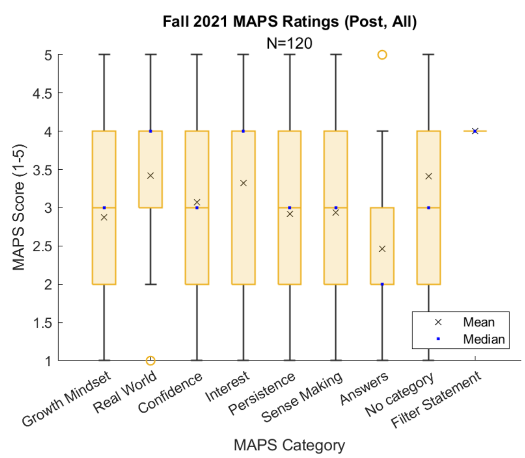

Figure 22: MAPS (Post, All)

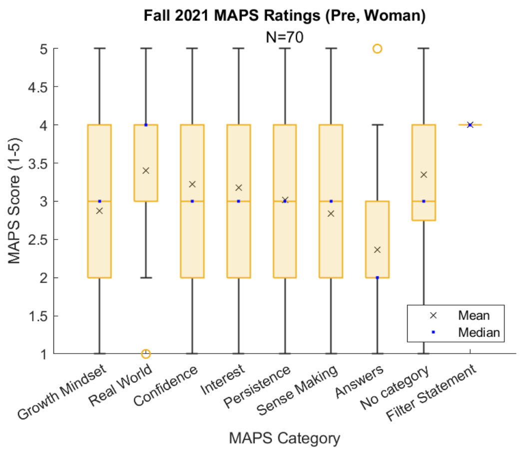

Figure 23: MAPS (Pre, Women)

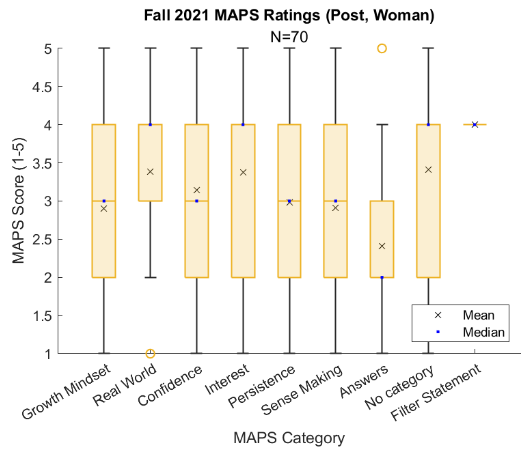

Figure 24: MAPS (Post, Women)

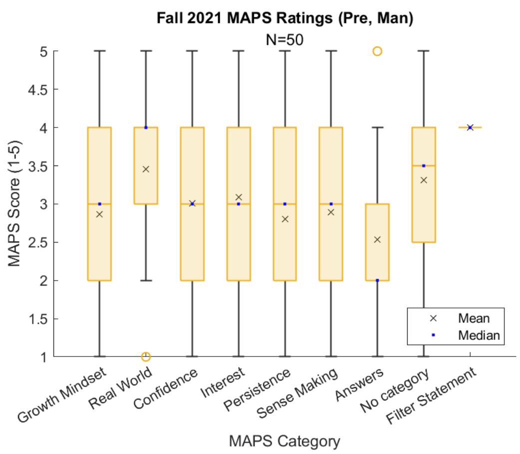

Figure 25: MAPS (Pre, Men)

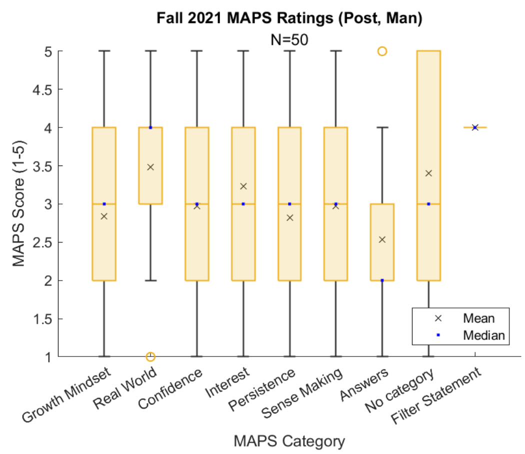

Figure 26: MAPS (Post, Men)

4.5 Spring 2022 (All Students)

Overall, the MAPS category means had little variation between pre and post-responses. The MAPS category with the lowest mean rating value was Answers (2.5931 pre, 2.7483 post), suggesting that during spring 2022 students appeared to find more value in applying than memorizing mathematical formulas/concepts, although women appeared to find more value (2.5748 pre, 2.7517 post) in applying than memorizing mathematical formulas/concepts than men (2.7050 pre, 2.7898 post).

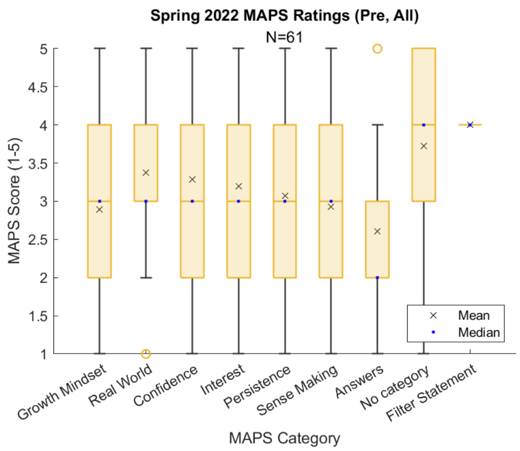

Figure 27: MAPS (Pre, All)

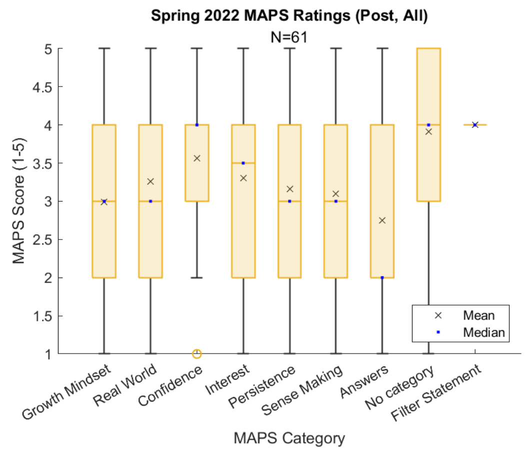

Figure 28: MAPS (Post, All)

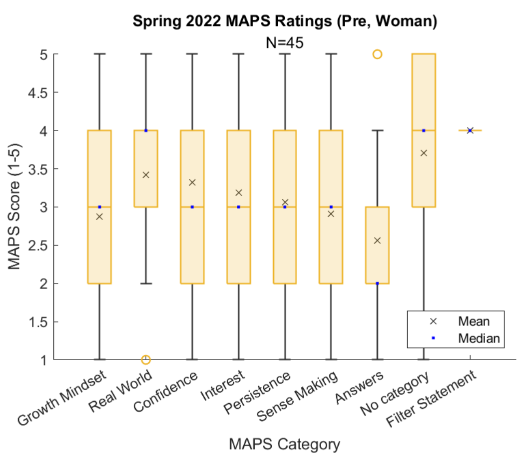

Figure 29: MAPS (Pre, Women)

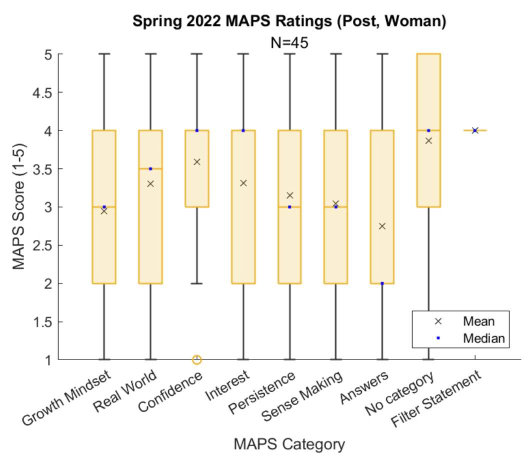

Figure 30: MAPS (Post, Women)

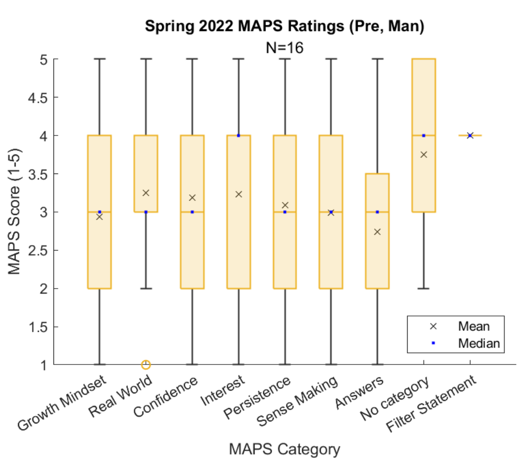

Figure 31: MAPS (Pre, Men)

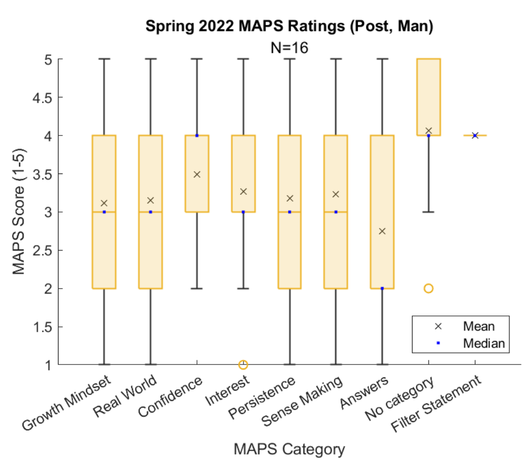

Figure 32: MAPS (Post, Men)

4.6 Desired Major

The last question in the MAPS questionnaire asked students to state their intended major. While this paper originally aimed to examine the percentage of students who desired to pursue a STEM or non-STEM degree, there were too few students who intended to pursue a non-STEM for those results to be made public. In order to protect the privacy of the study participants, this paper examined the percentage of students who desired to pursue an engineering or non-engineering degree.

During fall 2020, 76% of students intended to pursue a major in the College of Arts and Sciences. 24% of students intended to pursue a major in the School of Engineering. These percentages are consistent for the pre and post-responses. During fall 2021, 67% of students intended to pursue a major in the College of Arts and Sciences. 33% of students intended to pursue a major in the School of Engineering. These percentages are consistent for the pre and post-responses. During spring 2022, 100% of students intended to pursue a major in the College of Arts and Sciences. 0% of students intended to pursue a major in the School of Engineering. These percentages are consistent for the pre and post-responses.

5. Discussion

Across all course offerings, there was little variation between the pre and post MAPS and TAI-5 category means responses, even when separated by gender. In addition, no category had a mean difference large enough to shift the average rating response (e.g., Agree to Strongly Agree). These results could be due to the following potential limitations, each of which can be altered in future research. The lack of consistent variables between course offerings makes it difficult to analyze the true effect of varying Calculus I classroom styles. Therefore, future work can vary only one of the following: Class type, Grading type, Instructor, and Delivery.

Since two of the course offerings were taught during the COVID-19 pandemic, which may have added confounding variables to student academic experiences, potentially affecting student attitudes and perceptions toward mathematics. Therefore, future work would ideally examine courses that are in more consistent states of the world.

In addition, the MAPS and TAI-5 questionnaires have a small rating scale (1-5 and 1-4, respectively). Consequently, students may be less likely to choose the minimum and maximum ratings values when taking the survey, causing the differences in mean category ratings to remain approximately consistent. In order to reduce the effect of this potential limitation, future work can use a 7-point rating scale [20].

Finally, about 70% of the students who filled out the pre-survey did not fill out the post-survey; N=712 pre-surveys were collected, and only N=209 post-surveys were collected. As a result, there was a significant amount of student data that was not able to be used in this paper. Future studies can consider incentivizing the filling out of each survey in order to better represent the sample population.

This paper investigated how a student's desire to pursue a STEM (specifically engineering) degree was affected by the style of their Calculus I course. It found that no one particular type of Calculus I course appears to affect students' desired major. Across all semesters, very few (N=3) students shifted their intended major. Of those who changed their intended major, the shift was not between the College of Arts and Sciences and the School of Engineering.

In addition, this paper investigated the relationship between the style of Calculus I courses taken at the undergraduate level and students' overall attitudes and perceptions toward mathematics. The mean MAPS and TAI-5 category rating values were approximately similar across all semesters when comparing her pre and post-survey responses. While some categories had a change in the interquartile range of responses, no category had a mean difference large enough to shift the average rating response (e.g., Agree to Strongly Agree). These results are consistent even when the data is separated by gender.

6. Appendix

Table 2: MAPS Questions

Question Number	***Question***
1.	*After I study a topic in math and feel that I understand it, I have difficulty solving problems on the same topic.*
2.	*There is usually only one correct approach to solving a math problem.*
3.	*I'm satisfied if I can do the exercises for a math topic, even if I don't understand how everything works.*
4.	*I do not expect formulas to help my understanding of mathematical ideas, they are just for doing calculations.*
5.	*Math ability is something about a person that cannot be changed very much.*
6.	*Nearly everyone is capable of understanding math if they work at it.*
7.	*Understanding math means being able to recall something you've read or been shown.*
8.	*If I am stuck on a math problem for more than ten minutes, I give up or get help from someone else.*
9.	*I expect the answers to math problems to be numbers.*
10.	*If I don't remember a particular formula needed to solve a problem on a math exam, there's nothing much I can do to come up with it.*
11.	*In math, it is important for me to make sense out of formulas and procedures before I use them.*
12.	*I enjoy solving math problems.*
13.	*Learning math changes my ideas about how the world works.*

14.	*I often have difficulty organizing my thoughts during a math test.*
15.	*Reasoning skills used to understand math can be helpful to me in my everyday life.*
16.	*To learn math, the best approach for me is to memorize solutions to sample problems.*
17.	*No matter how much I prepare, I am still not confident when taking math tests.*
18.	*It is a waste of time to understand where math formulas come from.*
19.	*We use this statement to discard the survey of people who are not reading the questions. Please select Agree (not Strongly Agree) for this question. (Filter statement; discard data for respondents that do not choose Agree here.)*
20.	*I can usually figure out a way to solve math problems.*
21.	*School mathematics has little to do with what I experience in the real world.*
22.	*Being good at math requires natural (i.e. innate, inborn) intelligence in math.*
23.	*When I am solving a math problem, if I can see a formula that applies then I don't worry about the underlying concepts.*
24.	*If I get stuck on a math problem, there is no chance that I will figure it out on my own.*
25.	*When learning something new in math, I relate it to what I already know rather than just memorizing it the way it is presented.*
26.	*I avoid solving math problems when possible.*
27.	*I think it is unfair to expect me to solve a math problem that is not similar to any example given in class or the textbook, even if the topic has been covered in the course.*
28.	*All I need to solve a math problem is to have the necessary formulas.*
29.	*I get upset easily when I am stuck on a math problem.*
30.	*Showing intermediate steps for a math problem is not important as long as I can find the correct answer.*
31.	*For each person, there are math concepts that they would never be able to understand, even if they tried.*
32.	*I only learn math when it is required.*

The Mathematics Attitudes and Perceptions Survey (MAPS) instrument consists of the above 31 statements and 1 filter statement. This survey can be offered in either an online or written form. Students respond to each question using a 5-point Likert format: “Strongly Disagree”, “Disagree”, “Neutral”, “Agree”, and “Strongly Agree”. The student receives 1 point for a question if their answer is in the same direction—that is, in the disagree or agree direction—as the expert consensus, given at the end of each question above. If the student responds in the opposite direction of the expert consensus, or a neutral response is given, they receive 0 for that question. The total expertise index is calculated by averaging the scores for all questions except 19, 22, and 31. Subscale scores are calculated analogously, with the question numbers comprising each category given in Table 3.

Table 3: MAPS Categories and Corresponding Question Numbers

Category	***Question Number***
Growth Mindset	*5, 6, 22, 31*
Real World	*13, 15, 21, 25*
Confidence	*1, 14, 17, 20*
Interest	*12, 26, 32*
Persistence	*8, 10, 24, 29*
Sensemaking	*3, 4, 11, 18, 23*
Answers	*2, 7, 9, 16, 28, 30*
No category but scored for expertise	*27*
Filter Statement	*19*
Expertise (expert consensus)	*All except 19, 22, and 31*

Table 3 demonstrates how the 32 MAPS questions can be broken down into subsections of various categories that relate to student attitudes and perceptions toward mathematics.

Table 4: Short Form Test Anxiety Inventory (TAI-5) Questions

Question Number	***Question***
33.	*During tests I feel very tense.*
34.	*I wish examinations did not bother me so much.*
35.	*I seem to defeat myself while working on important tests.*
36.	*I feel very panicky when I take an important test.*
37.	*During examinations I get so nervous that I forget facts I really know.*

The five questions listed in Table 4 were added to the fall 2021 and spring 2022 MAPS surveys in order to collect additional information on student attitudes and perceptions toward mathematics. These five questions are considered to be a short form of the Test Anxiety Inventory (TAI), which is widely used in research and practical settings and has particular application to the assessment and treatment of test anxiety in student populations. They were added to the survey to efficiently determine how student attitudes and perceptions towards mathematics were impacted by the presence of examinations.

Table 5: Demographic Questions

Question Number	***Question***
38.	*In what math course are you currently enrolled?*
39.	*How would you describe yourself? (Select all that apply.)*
40.	*How would you describe yourself? (Select all that apply.)*
41.	*If known, what is your intended (or declared) major?*

The 4 questions listed above in Table 5 were added to the MAPS survey to collect information on student demographics. These questions were asked in order to determine if student identity impacted their perceptions and attitudes toward mathematics. To answer Question 38, students chose from a drop-down of options of course sections and instructors. To answer Question 39, students selected from the following racial categories: American Indian, Alaska Native, First Nations, or Indigenous; Asian or Asian American; Black or African American; Hispanic, Latino/a/x, or Spanish origin; Middle Eastern or North African; Native Hawaiian or other Pacific Islander; White or Caucasian; Another race, ethnicity, or origin. Please specify; I prefer not to respond. Question 40 was also answered by students selecting one of the following categories: Woman; Man; Non-binary/Genderqueer; Trans (i.e. transgender, transwoman, transman, etc.); I prefer to self-describe. Please specify; I prefer not to respond. Question 41 was an open-ended response that was later coded during data analysis as a STEM or non-STEM major in order to assess the impact of introductory mathematics on student desire to pursue a STEM degree. In order to protect student privacy, this paper only discusses the results by gender and intended major demographics.

Table 6: MAPS+TAI-5 Category Ratings for Calculus I (fall 2020, fall 2021, spring 2022)

MAPS Category (1-5 scale)	***Time of Rating***	***Mean Fall 2020 Rating (Remote, S/U grading) N=28***	***Mean Fall 2021 Rating (Hybrid, Letter grading) N=120***	***Mean Spring 2022 Rating (In-person, Letter grading) N=61***
Growth Mindset	*Pre:*	*3.3065*	*2.8729*	*2.8971*
	Post:	*3.2339*	*2.8762*	*2.9712*
	Post-Pre:	***-0.0726***	***0.0033***	***0.0741***
Real World	*Pre:*	*2.5806*	*3.4229*	*3.3934*
	Post:	*2.6290*	*3.4194*	*3.2612*
	Post-Pre:	***0.0484***	***-0.0036***	***-0.1322***
Confidence	*Pre:*	*3.0887*	*2.9458*	*3.0478*
	Post:	*3.0242*	*2.9360*	*3.2538*
	Post-Pre:	***-0.0645***	***-0.0098***	***0.2060***
Interest	*Pre:*	*3.0108*	*3.1528*	*3.2402*
	Post:	*2.8925*	*3.3277*	*3.3284*
	Post-Pre:	***-0.1183***	***0.1749***	***0.0882***
Persistence	*Pre:*	*3.2016*	*2.9278*	*3.0294*
	Post:	*3.4194*	*2.9258*	*3.1343*
	Post-Pre:	***0.2177***	***-0.0020***	***0.1049***
Sense Making	*Pre:*	*3.2774*	*2.8650*	*2.9029*
	Post:	*3.1161*	*2.9461*	*3.0667*
	Post-Pre:	***-0.1613***	***0.0811***	***0.1638***
Answers	*Pre:*	*3.5699*	*2.4333*	*2.5931*
	Post:	*3.5484*	*2.4601*	*2.7483*
	Post-Pre:	***-0.0215***	***0.0267***	***0.1551***
Expertise (expert consensus)	*Pre:*	*3.1212*	*2.9613*	*3.0492*
	Post:	*3.1012*	*2.9939*	*3.1594*
	Post-Pre:	***-0.0200***	***0.0325***	***0.1102***
TAI-5 Questions (1-4 scale)	*Pre:*	*N/A*	*2.6437*	*2.7592*
	Post:	*N/A*	*2.4526*	*2.8320*
	Post-Pre:	***N/A***	***-0.1910***	***0.0728***

Table 6 consists of the average score for the MAPS categories and TAI-5 questions. It used the paired data (not separated by "woman" or "man" demographic) for fall 2020, fall 2021, and spring 2022 semesters.

Table 7: MAPS Category Ratings for Calculus I (fall 2020, fall 2021, spring 2022) by Gender

MAPS Category (1-5 scale)	***Time of Rating***	***Mean Fall 2020 Rating (Remote, S/U grading)***		***Mean Fall 2021 Rating (Hybrid, Letter grading)***		***Mean Spring 2022 Rating (In-person, Letter grading)***	
		Woman N=16	***Man N=12***	***Woman N=71***	***Man N=49***	***Woman N=45***	***Man N=16***
Growth Mindset	*Pre:*	*3.3594*	*3.2500*	*2.8821*	*2.8622*	*2.8827*	*3.0000*
	Post:	*3.3750*	*3.0833*	*2.9010*	*2.8486*	*2.9490*	*3.1066*
	Post-Pre:	***0.0156***	***-0.1667***	***0.0189***	***-0.0136***	***0.0663***	***0.1066***
Real World	*Pre:*	*2.7500*	*2.4000*	*3.4036*	*3.4490*	*3.4184*	*3.2941*
	Post:	*2.6563*	*2.6000*	*3.3800*	*3.4844*	*3.3010*	*3.1875*
	Post-Pre:	***-0.0936***	***0.2000***	***-0.0236***	***0.0354***	***-0.1173***	***-0.1066***
Confidence	*Pre:*	*3.000*	*3.1833*	*2.9786*	*2.8878*	*3.0612*	*3.0441*
	Post:	*3.0156*	*3.0333*	*2.9350*	*2.9101*	*3.2398*	*3.3208*
	Post-Pre:	***0.0156***	***-0.1500***	***-0.0436***	***0.0223***	***0.1786***	***0.2767***
Interest	*Pre:*	*2.9583*	*3.0667*	*3.1857*	*3.1020*	*3.2449*	*3.2157*
	Post:	*2.6875*	*3.111*	*3.3816*	*3.2431*	*3.3265*	*3.3125*
	Post-Pre:	***-0.2708***	***0.0444***	***0.1959***	***0.1410***	***0.0816***	***0.0968***
Persistence	*Pre:*	*3.0313*	*3.3833*	*3.0036*	*2.8174*	*3.0561*	*3.0000*
	Post:	*3.2500*	*3.6000*	*2.9855*	*2.8177*	*3.1582*	*3.2188*
	Post-Pre:	***0.2187***	***0.2167***	***-0.0181***	***0.0003***	***0.1020***	***0.2188***
Sense Making	*Pre:*	*3.1625*	*3.4000*	*2.8343*	*2.9020*	*2.8898*	*2.9765*
	Post:	*3.0500*	*3.1867*	*2.9123*	*2.9850*	*3.0286*	*3.2706*
	Post-Pre:	***-0.1125***	***-0.2133***	***0.0781***	***0.0830***	***0.1388***	***0.2941***
Answers	*Pre:*	*3.5521*	*3.5889*	*2.3667*	*2.5272*	*2.5748*	*2.7059*
	Post:	*3.5417*	*3.5556*	*2.4080*	*2.5271*	*2.7517*	*2.7898*
	Post-Pre:	***-0.0104***	***-0.0333***	***0.0413***	***-0.0001***	***0.1769***	***0.0839***
Expertise (expert consensus)	*Pre:*	*3.0905*	*3.1540*	*2.9660*	*2.9488*	*3.0619*	*3.0426*
	Post:	*3.0496*	*3.1563*	*2.9968*	*2.9794*	*3.1645*	*3.2041*
	Post-Pre:	***-0.0409***	***0.0023***	***0.0308***	***0.0307***	***0.1025***	***0.1615***
TAI-5 Questions (1-4 scale)	*Pre:*	*N/A*	*N/A*	*2.9486*	*2.3388*	*2.9184*	*2.6000*
	Post:	*N/A*	*N/A*	*2.7391*	*2.1661*	*2.9265*	*2.7375*
	Post-Pre:	***N/A***	***N/A***	***-0.2094***	***-0.1726***	***0.0082***	***0.1375***

Table 7 consists of the average score for the MAPS categories and TAI-5 questions. It used the paired data (separated by "woman" or "man" demographic) for fall 2020, fall 2021, and spring 2022 semesters.

Table 8: Calculus I Desired Major (fall 2020, fall 2021, spring 2022)

Desired/Intended/ Declared Major	***Time of Rating***	***Mean Fall 2020 Rating (Remote,***	***Mean Fall 2021 Rating (Hybrid,***	***Mean Spring 2022 Rating (In-person,***

		S/U grading) N=24	Letter grading) N=92	Letter grading) N=56
STEM	Pre:	0.9200	0.9239	0.8793
	Post:	0.9600	0.9239	0.9655
	Post-Pre:	**0.0400**	**0.0000**	**0.0862**
Non-STEM	Pre:	0.0000	0.0435	0.0690
	Post:	0.0000	0.0652	0.0345
	Post-Pre:	**0.0000**	**0.0217**	**-0.0345**
Undecided	Pre:	0.0800	0.0326	0.0517
	Post:	0.0400	0.0109	0.0000
	Post-Pre:	-0.0400	**-0.0217**	**-0.0517**

Table 8 consists of the categorization of paired student responses to survey question 41. Their major was categorized as STEM, non-STEM, or undecided. The responses of students who left the question blank were not included in the calculations.

Table 9: Calculus I Desired Major By Gender (fall 2020, fall 2021, spring 2022)

Desired/Intended/ Declared Major	Time of Rating	Mean Fall 2020 Rating (Remote, S/U grading)		Mean Fall 2021 Rating (Hybrid, Letter grading)		Mean Spring 2022 Rating (In-person, Letter grading)	
		Woman N=12	Man N=12	Woman N=53	Man N=39	Woman N=41	Man N=15
STEM	Pre:	0.9167	0.9231	0.8868	0.8974	0.8537	0.9333
	Post:	1.0000	0.9231	0.9057	0.9487	0.9756	0.9333
	Post-Pre:	**0.0833**	**0.0000**	**0.0189**	**0.0513**	**0.0122**	**0.0000**
Non-STEM	Pre:	0.0000	0.0000	0.0567	0.0256	0.0732	0.0667
	Post:	0.0000	0.0000	0.0754	0.0513	0.0244	0.0667
	Post-Pre:	**0.0000**	**0.0000**	**0.0187**	**0.0257**	**-0.0488**	**0.0000**
Undecided	Pre:	0.0833	0.0769	0.0567	0.0769	0.0732	0.0000
	Post:	0.0000	0.0769	0.0189	0.0000	0.0000	0.0000
	Post-Pre:	**-0.0833**	**0.0000**	**-0.0378**	**-0.0769**	**-0.0732**	**0.0000**

Table 9 consists of the categorization, separated by the "woman" or "man" demographic, of matched student responses to survey question 41. Their major was categorized as STEM, non-STEM, or undecided. The responses of students who left the question blank were not included in the calculations.

7. References

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