Gender, switching, and student perceptions of Calculus I

Jessica Ellis
Colorado State University

Rebecca Cooper
Colorado State University

We analyze survey data to explore how students' reported perceptions of their Calculus I experiences relate to their gender and persistence in calculus. We draw from student free-responses from several universities involved in a comprehensive US national study of Calculus I We perform a thematic analysis on the data, identifying numeric patterns via Dedoose, a mixed methods program, and inspecting student responses within identified themes. Our analyses indicate that female students report negative affect and a desire for authentic learning more often than males. Student preparation also plays a role in changes in confidence. We discuss potential factors that influence student persistence in calculus.

Keywords: Calculus, gender, persistence, affect, thematic analysis, mixed methods

Stemming from national need to increase persistence in Science, Technology, Engineering, and Mathematics (STEM), Ellis, Fosdick, and Rasmussen conducted a study focused on student persistence in calculus and investigated factors which may impact the likelihood of a student switching out of a STEM major (2015). They identified a striking relationship between gender, switching, and mathematical confidence. Specifically, females were significantly more likely to decrease their intentions to take Calculus II after taking Calculus I. When given a list of potential reasons for not continuing, female students cited that they, "do not believe [they] understand the ideas of Calculus I well enough to take Calculus II," with significantly greater frequency than their male counterparts. These results highlight the role that calculus is playing in students' decisions to leave STEM pursuits, and may help to explain the larger issue of the STEM Gender Gap (Eagan, Lozano, Hurtado, & Case, 2013; Seymour & Hewitt, 1997). This work motivated us to delve more deeply into student reports of their experiences in Calculus I. Specifically, we examine the relationships between students' description of their experience in Calculus I, their gender, and their decisions to persist in calculus.

Educators have long been interested in identifying factors that may contribute to the disparity in gender representation in STEM (Fennema & Sherman, 1976 & 1978; Griffith, 2010; Good, Rattan, & Dweck, 2012; Ellis, Fosdick, & Rasmussen, 2015). While there is consistent evidence against gender-based differences in mathematical ability (Fennema & Sherman, 1978; Islam, & Al-Ghassani, 2015; Lindberg, Hyde, & Peterson, 2010), there are clear distinctions between men and women in their persistence in STEM fields (Cunnigham, Hover, & Sparks, 2015; Eagan et al., 2013), and their self-reports of success in these fields (Griffith, 2010; Good, Rattan, & Dweck, 2012).

Researchers have begun to articulate factors related to persistence and the representation of females and other minorities in STEM majors (Ellis, Fosdick, & Rasmussen, 2015; Fennema & Sherman, 1976; Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013; Griffith, 2010; Wolniak, Mayhew, & Engberg, 2012). Griffith found that certain environmental factors (such as the representation of females and minorities in graduate programs) can increase STEM participation and success by minorities (2010). Good, Rattan, and Dweck (2012) found that a sense of belonging was related to student persistence in math and that women who exhibited a fixed intelligence mindset coupled with gender stereotyping in the classroom experienced reduced sense of belonging (2012). Gender differences in confidence have also been identified as

a possible factor to explain why women discontinue pursuing mathematics at a higher rate than men (Ellis, Fosdick, & Rasmussen, 2015; Fennema & Sherman, 1978).

Our research contributes to this literature by offering an inductive, qualitative analysis of student statements pertaining to their experiences in Calculus I. We draw on students' responses to an open-ended survey question from the *Characteristics of Successful Programs in College Calculus (CSPCC)* project.

In this report we address the following research question: *How do student characterizations of their experience in Calculus I relate to student gender and persistence in calculus?*

Methods

This work is embedded within a larger project aimed at investigating college calculus at a national level – the CSPCC project. The first phase of this work involved a survey of "mainstream" Calculus I students from a stratified random sample of colleges and universities. Two surveys were sent to students at the beginning and the end of the fall term. On the beginning-of-term survey, students were asked questions related to their demographics, previous mathematical experiences, affect towards mathematics, and career plans. On the end-of-term survey, students were asked questions related to their experience in Calculus I, affect towards mathematics, and career plans. At the end of the end-of-term survey, students were asked the open-ended question: "Is there anything else you want to tell us about your experience in Calculus I?" We analyze students' responses to this question in this report. The surveys provide us with information to distinguish students based on gender and whether they continued in calculus. Students who began Calculus I intending to take Calculus II and persisted in these intentions are referred to as *Persisters,* while students who began Calculus I intending to take Calculus II and switched these intentions are referred to as *Switchers.*

There were 522 students who provided a response to the open-ended question, reported their gender in the beginning of the term survey, and were coded as a Switcher or a Persister. To characterize the ways these students discussed their experiences in Calculus I, and to relate these characterizations to student gender and persistence, we employed thematic analysis (Braun & Clarke, 2006).

In this analysis we first familiarized ourselves with the student responses, blind to the gender and persistence of the students, though aware of the literature related to the STEM gender gap and, more specifically, aware of the relationship in this data set between gender, reported mathematical confidence, and persistence in calculus. We took an inductive approach, deriving themes from the data, but we brought to bear our knowledge of the literature in organizing these themes. The two authors each coded subsets of 50 student responses to develop and refine codes. The final codes, reported in Table 1, were finalized after multiple iterations of comparing codes and once 85% reliability was consistently achieved between researchers. One researcher then coded all responses, with a small percentage of questionable responses coded by both researchers. We weighted the codes on a scale of -1 to 1 to indicate a negative, neutral, or positive connotation. For each student response, we coded each sentence with as many codes as appropriate. The NA code was only used if the entire student response was irrelevant.

To frame this work we draw on literature surrounding affect. We define and understand affect according to Phillip's summary of research done on mathematical belief and affect from the years 1992 to 2007. By consolidating definitions from research, Phillip defines affect as "a disposition or tendency or an emotion or feeling attached to an idea or object. Affect is comprised of emotions, attitudes, and beliefs" (Phillip, 2007, p. 259). In our examination of

students' open-ended responses about Calculus I, we analyze students' reported affect towards Calculus I. Nearly all students' responses could be viewed as affective statements. Thus, we narrowed our use of the "Affect" code to only capture statements about a student's emotions, attitudes, or beliefs towards the calculus course, oneself as a learner, or mathematics in general. For instance, "*This professor is pretty good at explaining the concepts*," is an example of a response that was coded as being about the teacher but not as a report of the student's affect. By contrast, "*I feel that I am loving math because my professor loves to teach it. She makes class so much fun and she believes in us*," is an example of a response that was coded with both the "Teacher" and "Affect" codes.

Table 1. Codes, code descriptions, and examples.

Code	Includes statements about…
Affect	Student's emotions, attitudes, and beliefs about (a) the calculus course, (b) mathematics, (c) themselves as learners. *For the first time in my life I really struggled in a math class.*
Assignments and assessments	Assignments, and both formative and summative assessments. *The exams tended to be stressful/time consuming.*
Pacing	The pacing of the course in general and of class sessions. *The length of class … didn't really allow for … anything rather than the 'spewing' of material*
Preparation	Preparation coming into the course and preparation going into the next course. *Taking calculus in high school helped me succeed in this class!*
TA	The TA and his/her aspects such as communication, availability, helpfulness, etc. *The help desk hours with the T.A. were great.*
Teacher	The teacher and his/her aspects such as communication, availability, helpfulness, etc. *I thoroughly enjoyed my professors teaching style and presentation of material.*
Teaching	Specific teaching practices and teacher-controlled aspects of class room environment. *My instructor …had no passion for learning and lectured instead of taught.*
Other	Other reasons and resources that may have impacted the student's success *Without the math tutoring lab there is no way I would do well in this class or even pass.*
Not applicable	Anything irrelevant to the calculus course. *If a teacher truly loves the subject, students can tell and learn to love it too.*

Once the responses were coded, we used a software program called Dedoose to identify patterns between the coding, student gender, and persistence. Dedoose allowed us to easily identify the prevalence of codes in our data set, check code co-occurrence, and view student descriptor information.

Results

To understand the relationships between students' responses, their gender, and their calculus persistence, we provide an overview of the distribution of the most prevalent codes among the four categories of students in Table 2. Of the 522 original student responses, 68 were coded as not applicable and were filtered out, leaving 454 relevant comments. Half of these comments came from Male Persisters, 9% from Male Switchers, 32% from Female Persisters, and 10% from Female Switchers. Among all students, the most frequent responses were related to Affect, the Teacher, Assignments and Assessments, and Preparation. However, the frequency of these responses within each student group varies; for instance, 37% of Male Persisters' responses were coded as Affect while 63% of Male Switchers' responses were coded this way.

Table 2. Prevalence of codes among four student groups.

	Male Persister *(n=268)*	**Male Switcher** *(n=43)*	**Female Persister** *(n=160)*	**Female Switcher** *(n=51)*
Affect *(n=238)*	37%	63%	51%	61%
Teacher *(n=182)*	32%	26%	43%	35%
A&A *(n=109)*	19%	16%	24%	24%
Prep *(n=82)*	12%	21%	19%	22%
Content *(n=78)*	16%	9%	14%	16%
Teaching *(n=76)*	15%	12%	13%	18%
Pacing *(n=18)*	3%	5%	4%	2%
Other *(n=54)*	7%	9%	16%	8%

Much research has been done on mathematical affect and its role in student persistence (Ellis, Fosdick, & Rasmussen, 2015; Fennema & Sherman, 1978; Good, Rattan, & Dweck, 2012). In our data, affect was the most pervasive code – and more so among Switchers than Persisters. As shown in Table 3, of the 238 responses coded with affect, the majority were coded with a positive weight (109), followed by 71 weighted negative, 62 neutral, and 8 responses coded with mixed affect, such as including both a positive affect statement and a negative affect statement.

Table 3. Prevalence of codes among four student groups.

Affect	**Male Persister** *(n=99)*	**Male Switcher** *(n=27)*	**Female Persister** *(n=81)*	**Female Switcher** *(n=31)*
Negative *(n=71)*	23%	37%	28%	48%
Neutral *(n=62)*	18%	26%	22%	29%
Positive *(n=107)*	56%	37%	43%	23%
Mixed *(n=8)*	3%	0%	6%	0%

Among the 99 Male Persisters' responses coded Affect, the majority (56%) were positive followed by 23% negative responses. Among the 27 Male Switchers, 37% of the Affect responses were negative and 37% were positive. Among the 81 Female Persisters, 43% were positive and 28% were negative. Strikingly, among the 31 Female Switchers, 48% of the Affect responses were weighted negative and only 23% were positive. These results indicate that Switchers, both men and women, are more likely to comment on their experience in Calculus I with an Affect statement (as shown in Table 2) and more likely for their Affect statements to be negative (as shown in Table 3). In order to better understand what aspects of their experiences in Calculus I the students expressed emotions, attitudes, or beliefs about we investigated the patterns that emerged within the Affect coding. Many interesting patterns emerged from the data within the coding, especially in the relationships among gender, persistence, and responses that were coded with Affect as well as something else. These responses point to aspects of Calculus I that students were especially emphatic about (either positively or negatively) and that possibly had a role in their decisions to persist in calculus. In this report, we focus on responses that are coded in such a way as to fall under the overlap of Affect and Teacher as well as Affect and Preparation. We investigated these relationships further by conducting a second level of thematic analysis on the responses.

Affect and Teaching

First, we analyzed the student responses coded with Affect and Teacher. Though thematic analysis, we refined the analysis further to uncover three subthemes related to affect – affect towards self, affect towards the course, and affect towards math. In this report, we focus on the most prevalent affect subtheme, affect towards self, and what role the teacher plays.

Statements coded with affect towards self entailed evaluations of personal learning and sometimes of self-worth. Usually, the comments merely focused on how well students learned in the course, but some comments were more personal and connected performance in the classroom to assessment of their intelligence or ability. This subtheme was weighted -2, 1, 0, 1, or 2 to designate a negative change in self-perception, negative self-perception, a neutral view of self, positive self-perception, and a positive change in self-perception, respectively.

As seen in Table 4, over half of Male Persister affect towards self comments were negative. This proportion grew for Male Switchers. Female Persister made more Affect towards self/ Teacher comments in general, and their responses were spread across the entire spectrum of the subtheme. They were the only student group to report a negative change in affect or positive affect. Female Switchers also had a high proportion of negative comments.

Table 4. Prevalence of Affect towards self/ Teacher subtheme and its weights among four student groups.

	Male Persister	**Male Switcher**	**Female Persister**	**Female Switcher**
Affect towards self *(n=37)*	9	3	20	5
Negative change (n=4)	0%	0%	20%	0%
Negative (n=16)	56%	67%	30%	60%
Neutral (n=10)	22%	33%	25%	40%
Positive (n=4)	0%	0%	20%	0%
Positive change (n=3)	22%	0%	5%	0%

An analysis of the quotes themselves were more revealing of some interesting patterns. For the male Persisters reporting a negative change in self-perception, they mentioned possible major or career changes rather than changes in self-worth. The female Persisters made more personal statements, such as, "This class really made me question my abilities in math through the instructor's poor teaching methods… I have a strong math background. However, this class completely destroyed that for me." Among the students reporting negative self-perception, females generally made more personal statements than males, i.e. to report feeling stupid as opposed to struggling in the class. All student groups reported problems in the teacher's ability to communicate. However, only female students reported that teachers were not personable. One female Persister commented saying, "If you asked the wrong question or gave the wrong response, he had a tendency to make you feel stupid." Female Switchers also described teachers who made them feel badly about themselves.

For affect towards self, the neutral to positive change comments only mentioned learning and not more direct evaluations of self. Interestingly, males only outnumbered females in making affective statements when reporting a positive change in self-perception. For positive comments, both male and female students frequently mentioned teacher helpfulness, saying that the teacher presented challenging problems but made an effort to equip students to succeed.

Affect and Preparation

After determining that a large group of students' responses were coded with an Affect code and a Preparation code, we isolated this group of 45 responses and did a second level of analyses. These responses were reviewed and grouped based on emergent themes. Four main themes emerged, and 37 of the 45 codes fit into one of these four themes. These themes related to previous mathematical/calculus experience and how this affected their college calculus experience. The responses that did not fit into one of these themes either mentioned how they felt about their preparation moving forward (4), mentioned that they were repeating college calculus (3) or did not make a clear enough statement about their preparation to code as one of the above four codes (1).

The first theme related to having taken calculus in high school and that college calculus is in comparison worse, labeled "Bad in comparison". These responses indicated that students entered college calculus with certain expectations of what calculus is and expecting to easily succeed in college calculus since they already took the course. Often these students blame the negative experience in college calculus, in comparison to high school calculus, for their dissuasion from pursuing more mathematics. The second theme related to having taken calculus in high school and glad that they are retaking it, labeled "Felt prepared". These responses indicated that the students were appreciative of previously taken calculus and recognize that there was more to learn in college calculus. The third theme related to not having taken calculus in high school and feeling less prepared than others in the class because of this, labeled "Not prepared". These responses indicated that students were aware that many of their classmates had previously taken calculus, and that they were at a disadvantage because they had not taken it before. The final theme related to not having taken calculus in high school and feeling empowered because of their success, labeled "Empowered". These responses indicated that students were aware that many of their classmates had previously taken calculus and that they were in the minority for not, and so their success in the course in spite of this gave them increased confidence.

As shown in Table 4, among Male Persisters the most common Affect/Preparation response fell into the "Bad in Comparison" theme, closely followed by the "Empowered" theme. Among Female Persisters, the most common Affect/Preparation response also fell into the "Bad in Comparison" theme, closely followed by the "Felt Prepared" and "Not Prepared" themes no responses in the "Empowered" theme. Male Switchers had one response in each theme except for the "Empowered" theme, with two responses. All of the Female Switchers fell into the "Bad in Comparison" theme.

Table 4. Prevalence of Affect/ Preparation subthemes among four student groups.

	Male Persister *(n=11)*	**Male Switcher** *(n=5)*	**Female Persister** *(n=14)*	**Female Switcher** *(n=7)*
Bad in comparison *(n=20)*	45%	20%	50%	100%
Felt prepared *(n=6)*	9%	20%	29%	0%
Not prepared *(n=5)*	9%	20%	21%	0%
Empowered *(n=6)*	36%	40%	0%	0%

While these numbers are small, the patterns are surprising: of the men whose responses who were coded as Preparation and Affect, 50% (n=8) mentioned having taken high school calculus. Of these, only two "Felt Prepared". Of the women whose responses who were coded as Preparation and Affect, 86% (n=18) mentioned having taken high school calculus. Of these, none of the women Switchers but four of the women Persisters "Felt Prepared". Of the 50% of the men who did not have calculus before entering college, 6 were in the "Empowered" theme while none of the women were. These numbers indicate that for the men in our sample, entering college without having already taken calculus could be an empowering experience; while for women this was not the case. Instead, the vast majority of women in this sample had previously taken calculus in high school, and only some of the Persisters felt that this improved their time in college calculus.

Discussion

This work was motivated by work that clearly linked gender to persistence in calculus, with a lack of confidence in mathematical ability as a major contributing factor for women's decisions to leave calculus but not men's. In this report, we further investigated aspects of male and female Calculus I students' reports of their experience in calculus to try to better understand the link between gender and persistence in calculus. Our analyses identified a number of aspects of the Calculus I experience as related to gender and persistence.

Women reported affect towards self in relation to the teacher more often than men. Females' negative comments tended to relate their success directly to their self-worth. This may indicate that women are holding to a fixed intelligence mindset (Dweck, 2008). Due to the stereotyped nature of people who should perform well in math, a fixed mindset is especially detrimental to women and minorities (Good, Rattan, & Dweck, 2012). Females complained that teachers are not personable, while males did not. Unfriendly teaching practices may be reinforcing a fixed mindset, since students do not feel safe to make mistakes. Males and females made positive comments about teachers who challenged them, yet demonstrated a desire to help them succeed and took actions such as demonstrating multiple techniques to solve a problem. These actions are

more conducive to a growth mindset, which is beneficial for all students and could make a significant difference for underrepresented populations in STEM.

We also saw interesting differences in the way students discussed their preparation. Often, students who have taken calculus in high school are recommended to take Calculus I in college for a refresher, and easy introduction to what college math is like, or just to have an easier first semester. It seems that this advice may be frustrating many students, especially women, giving them an inflated perspective on their understanding of calculus, and results in them having a more negative experience in Calculus I.

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