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Women's Sense of Belonging in Undergraduate Calculus and the Influence of (Inter)Active Learning Opportunities

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Abstract: Women continue to be underrepresented in undergraduate STEM majors. Prior studies identify sense of belonging, or the extent to which one feels like an accepted member of an academic community, as a key contributor to women's decisions to stick with or leave their STEM majors. Calculus can be an especially critical leak in the STEM pipeline, as is often seen as a gatekeeper course for STEM majors. Historically, Calculus instruction has been primarily lecture-based, though recently, efforts have shifted toward incorporating instruction that supports active learning. Prior studies have suggested that providing active learning opportunities may support students' sense of belonging. However, there lacks consensus on the particular types of active learning opportunities that best support students. This mixed methods study investigates connections between women's sense of belonging and the learning opportunities they experience during the first semester of a two-semester Calculus course designed to provide frequent active learning opportunities. Findings indicate a significant increase in sense of belonging, perceived competence, and social connectedness from Week 1 to Week 7 of the semester. Further, women overwhelmingly identified the interactive nature of group work and interactive lecture as supportive of their sense of belonging for both academic and social reasons.

Keywords: *Calculus, Gender, Sense of Belonging, Undergraduate Education*

Introduction

Women continue to be underrepresented in science, technology, engineering, and mathematics (STEM), resulting in a lack of diversity that limits the field of scientific inquiry. Diversity benefits any field for a number of reasons. First, diversity is critical to excellence (Gibbs, 2014). Research is more typically conducted collaboratively rather than individually, and with more perspectives comes more and different approaches to solving problems. A more diverse workforce introduces the potential for identifying and tackling new types of problems that might not have been noticed in a more homogenous workforce. Second, diverse groups exhibit better problem-solving behaviors and hold more complex discussions than homogenous groups (Antonio et al., 2004; Hong & Page, 2004). Scientific inquiry is a field of problem-solving, and thus diversifying the STEM workforce would benefit the field.

The STEM gender gap is due at least in part to students' college major decisions (Carmichael, 2017; Chamberlain, 2017). Fewer women than men enter undergraduate STEM majors as first-year students (Eagan et al., 2016), and more women than men leave STEM. In fact, only about half of STEM-intending first-years complete a STEM degree, and of this already small proportion, women are 1.5 times as likely as men to switch out of STEM (Chen, 2013; Ellis et

al., 2016). As a result, far more men persist and graduate with STEM degrees than women, leading to a highly male-dominated STEM workforce.

Calculus can be an especially critical leak in the STEM pipeline and thus is a good site for investigation. Calculus is a required course for STEM majors, and it is often a prerequisite or corequisite for other STEM coursework. Thus, students who perform poorly in Calculus may be prevented from taking other courses for their major. Consequently, Calculus is a key junction at which students, especially women, decide whether to persist in STEM (Ellis et al., 2016; Rasmussen & Ellis, 2013; Seymour & Hunter, 2019).

One major factor that plays a role in students' decisions to leave STEM, particularly for women, is their sense of belonging (Seymour & Hunter, 2019; Shapiro & Sax, 2011). The goal of this study is to investigate women's sense of belonging in their first-year Calculus course and explore the potential of particular learning opportunities to support sense of belonging.

Literature Review & Theoretical Foundations

This study investigates connections between women's sense of belonging in Calculus and the learning opportunities they experience during their first-semester Calculus course. In this section, the constructs *sense of belonging* and *active learning* are defined, and a theoretical framework linking the two is developed.

Sense of Belonging

One feels a sense of belonging when they feel connected to a particular environment or feel accepted and appreciated by others in that environment (Rosenberg & McCullough, 1981). Strayhorn (2012) argues that sense of belonging can be so essential that one cannot engage in a space without feeling a sense of belonging in that space. For students, this might mean they have trouble listening to a lecture or studying for a test without first feeling that sense of belonging. In other words, students' sense of belonging in a class might influence if and how they engage and behave in that class. Good et al. (2012) conceptualize sense of belonging as "one's personal belief that one is an accepted member of an academic community whose presence and contributions are valued" (p. 701). So, to feel a sense of belonging in STEM simply means to feel valued and accepted within the STEM community. The current study adopts this definition.

Research indicates that students with a stronger sense of belonging in STEM are more likely to persist in STEM, and that women are less likely than men to develop a strong sense of belonging in STEM (Rainey et al., 2018; Seymour & Hunter, 2019; Shapiro & Sax, 2011; Thoman et al., 2013). In order to support women's sense of belonging in STEM, it is important to understand what types of things can influence one's sense of belonging. Research suggests that not only is sense of belonging malleable, but it can be influenced by things like learning environment, perceived competence, and social connectedness.

Prior studies have found that sense of belonging can change over time, though these changes have typically been negative (Anderman, 2003; Hausmann et al., 2007). However, in Anderman's (2003) study, decreases in sense of belonging were found to be mediated by students' positive perceptions of the learning environment. Lahdenperä and Nieminen (2020) investigated positive and negative contributors to students' sense of belonging in mathematics and also identified a link between students' perceptions of the learning environment and their sense of belonging. Further, Rainey et al. (2019) found that students who experienced a more active learning environment (as opposed to lecture-based) had greater perceptions of instructor care, which in turn related to a greater sense of belonging.

In Hausmann et al.'s (2007) study, while the sample reported a mean decrease, instances of individual students reporting an increase in sense of belonging were associated with greater academic integration than those who did not show increases. Academic integration refers to the extent to which the student feels like they understand the course material (i.e., their perceived competence) and feels like their instructor cares about their intellectual development (Tinto, 1975). Other studies have identified perceived competence as a contributor to sense of belonging as well. In their study with undergraduate Psychology and Linguistics students, Lewis and Hodges (2015) found that a low perceived competence was related to a low sense of belonging in their major. In Rainey et al.'s (2018) interview study with 201 college students who either persisted in or left STEM majors, students' perceived competence in STEM major-related material was the second most frequently reported contributor to their sense of belonging. Moreover, students who left STEM attributed their low sense of belonging to their low perceived competence. Additionally, researchers in sports psychology have found that perceived competence is malleable and that experiencing failure or being evaluated offer opportunitiys for perceptions of competence to change (Cole, 1991; Roberts et al., 1981).

Others identify the social connectedness students feel with their peer group and faculty as a contributor to their sense of belonging. Lewis and Hodges (2015) found that social fit contributed to students' sense of belonging in their major. Further, Rainey et al. (2018) detected the importance of social connectedness in their interview study – the most frequently cited contributor to sense of belonging in STEM, especially for women, was students' interpersonal relationships, or the extent to which one felt socially connected or similar to those around them in class. Furthermore, students who left STEM primarily attributed their low sense of belonging to their lack of interpersonal relationships. Finally, cognitive science and psychology researchers have shown that social connectedness can change over time (Taylor et al., 2020).

Studies like these indicate that sense of belonging is malleable and that factors like learning environment, perceived competence, and social connectedness might be influential to one's sense of belonging. Further, two of these influencing constructs (i.e., perceived competence and social connectedness) can also change over time. Next, active learning is defined and an explanation is provided for why active learning opportunities, particularly those that involve interaction, may be one way to bolster women's sense of belonging and keep them in the STEM pipeline.

Active Learning

Broadly speaking, active learning engages students in the learning process (Prince, 2004). More specifically, active learning is "the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert" (Bonwell & Eison, 1991, p. iii). In practice, this can entail having students work on problems in groups or individually during class, engaging students in whole-class discussions, using student response systems (e.g., clicker polls), and soliciting student questions and responses – essentially anything that is not strictly lecturing. Research indicates that students who are given opportunities to engage in active learning opportunities exhibit higher levels of achievement, sense of mastery, and persistence than students who are not provided these opportunities (Freeman et al., 2014; Lahdenperä et al., 2019; Rasmussen et al., 2019). In fact, the President's Council of Advisors on Science and Technology recommended in their 2012 report that undergraduate instructors implement active learning opportunities, especially in foundational STEM courses, as a way to retain more undergraduate students in STEM.

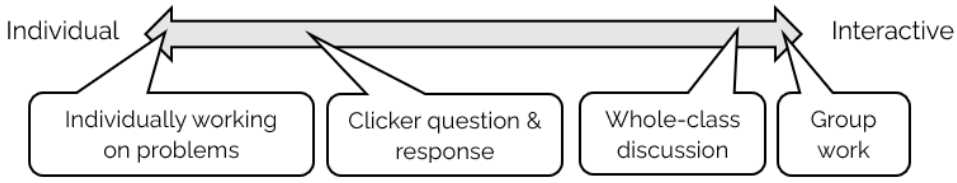
While these findings suggest that active learning can benefit all students, there is competing research on the effect of active learning for particular subgroups. Some scholars have found that students, especially women, typically prefer active learning to lecture, and active learning opportunities have been shown to benefit student performance and persistence more than lecture (Boaler, 1994; Seymour & Hunter, 2019). Further, Kogan and Laursen (2014) found that inquiry-based learning in a college mathematics course "leveled the playing field" (p. 415) in terms of men's and women's self-efficacy. However, others have found that positive outcomes are not always guaranteed. Johnson et al. (2019) found that men continued to outperform women in an inquiry-oriented abstract algebra course. Thus, further investigation is needed into which types of active learning opportunities might best support women's sense of belonging in their Calculus courses.

Theoretical Framework

Active learning is broad, and currently there is no consensus on the specific types of active learning opportunities that are most beneficial to particular groups of students. Note that some active learning opportunities are more solo (e.g., working on problems individually or responding to a clicker poll) while others involve interactions with others (e.g., engaging in group work or whole-class discussions). Active learning opportunities can be thought of as falling on a continuum (Figure 1; Griffin, 2021) with individual activities at one end and interactive activities at the other end. So, for example, individually working on problems and responding to clicker polls might fall more toward the individual end of the continuum, while group work and whole-class discussions would land at the interactive end.

Figure 1

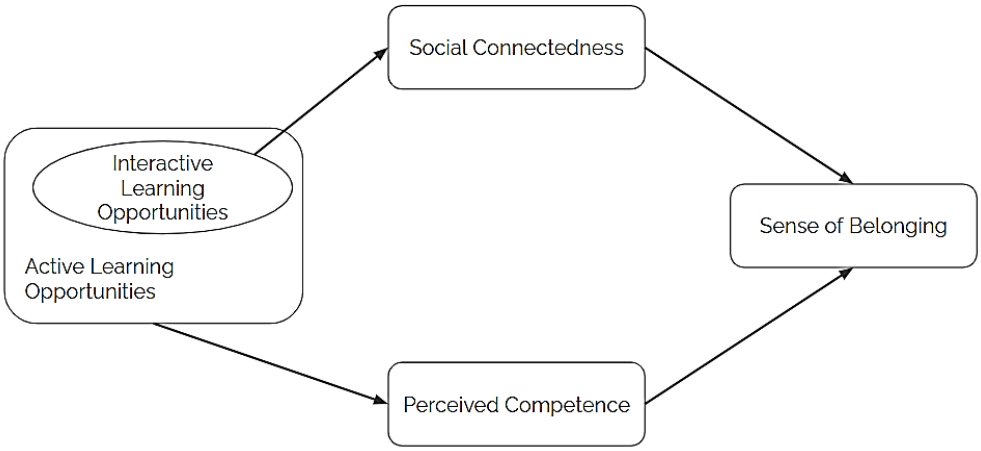
Active Learning Continuum



Providing opportunities to engage in active learning, especially interactive activities, offers promise in supporting women's sense of belonging in Calculus based on what we know about sense of belonging. Recall that students attribute their sense of belonging to factors like the learning environment, perceived competence, and social connectedness. Research suggests students, particularly women, have positive perceptions of active learning environments (Seymour & Hunter, 2019). Rainey et al. (2019) found that women who leave STEM reported experiencing lecture-based instruction while preferring active learning environments. Further, active learning supports students' achievement, perceived competence, and persistence (Freeman et al., 2014; Kogan & Laursen, 2014). Finally, certain types of active learning opportunities, particularly those toward the interactive end of the continuum, can offer students opportunities to interact with one another and with their instructor, thus supporting their social connectedness as well. Since active learning opportunities have the potential to invoke positive perceptions of the learning environment and support students' perceived competence and social connectedness, the presence of these opportunities, especially the more interactive types, could potentially support women's sense of belonging in Calculus (Figure 2).

Figure 2

Theoretical Framework Linking Active Learning Opportunities and Sense of Belonging



Purpose and Research Questions

The purpose of the larger study within which the current study is nested is (1) to examine the ways in which sense of belonging to mathematics and its contributing factors interact over one year for women enrolled in a year-long undergraduate Calculus course that incorporates frequent active learning opportunities, and (2) to investigate women's perceptions of if and how the active learning opportunities influenced their sense of belonging. This report focuses on the first seven weeks of the first semester of the course, examining women's experiences between the beginning and middle of the semester. Specifically, the following research questions are investigated: For undergraduate women enrolled in a year-long, active learning Calculus course,

(1) In what ways, if any, do their sense of belonging, perceived competence, and social connectedness change during the first half of the first semester?, and
(2) How do they characterize the influence of the learning opportunities they experience during class on their sense of belonging?

Methods

Feminist underpinnings have guided the decision to employ a transformative (feminist) mixed methodology to conduct this study (Creswell & Plano Clark, 2011). First, this study focuses on women's experiences in their introductory Calculus course without comparing them to men's experiences because women's experiences are worthy of examination in their own right (Du Bois, 2983; Kitzinger & Wilkinson, 1997). Comparing experiences between men and women implicitly positions the man as "norm" and the woman as "other" and further presents the woman as "less than" the man (Gilligan, 1982). Second, the qualitative strand of this study aims to include women's voices as a way to add nuance to the quantitative survey data. The quantitative and qualitative strands of this study are of equal priority.

Setting and Participants

This study is being conducted at a mid-sized R1 research university in the mid-Atlantic region of the U.S. during the 2022-2023 academic year. The university offers a year-long Integrated Calculus course for STEM majors (hereafter referred to as IC) as an alternative to the university's one-semester Calculus course for STEM majors. This course was designed for students who place into Pre-calculus but need STEM Calculus for their intended major. The course covers all of the core topics from the standard Calculus course, but weaves in necessary pre-calculus concepts and skills along the way. The first semester develops differential Calculus; the second semester develops integral Calculus. The course uses the Stewart et al. (2021) textbook as well as a second textbook specifically designed for integrating Calculus and Pre-calculus (Larson & Edwards, 2012). Students enrolled in the IC course are typically first-year students who have declared a STEM major or who are considering STEM.

The IC course has certain key features that are relevant to this study. First, the course is designed to incorporate frequent opportunities for students to engage in active learning. Specifically, each class session typically involves opportunities for students to work in small groups, participate in whole-class discussions, and contribute during interactive mini-lectures. To facilitate group work, the course is taught in a classroom furnished with circular tables and staffed by an undergraduate learning assistant who helps the instructor monitor students as they work in groups.

Second, the IC course is highly coordinated – in addition to common textbooks, homework assignments, and exams, the instructors teach from a collaboratively developed set of lesson plans that specify which math problems to use in each class and provide recommended active learning opportunities and a pacing guide. Instructors meet weekly to discuss the lessons and make refinements. As a result, students have very similar learning opportunities across different sections of this course.

Participants were students enrolled in the IC course during the Fall 2022 semester. Two sections of the course were offered, taught by two different instructors. All 127 students enrolled in these two sections received an email inviting them to participate in the study. All participants were asked to complete two surveys, one administered during the first week of the semester, and one during the seventh week of the 14-week semester. For this study, only students who self-identified as women and completed both surveys were considered for analysis, resulting in a final sample of 46 students.

Data Collection

To address the research questions, a survey was designed, distributed, and completed electronically using Qualtrics, a web-based survey tool. The first survey was administered during Week 1 of the semester and collected data about students' perceptions of their sense of belonging, perceived competence, and social connectedness. The second survey was administered during Week 7 of the semester and was almost identical to the first survey, except it also collected data on students' perceptions of how the classroom activities they experienced may have impacted their sense of belonging in math. Both surveys also collected demographic information such as gender.

A version of this survey was piloted in the Fall 2020 semester with a similar population of students (i.e., students enrolled in IC). Results of the pilot study were used to refine the survey to its current version. Most survey items come from previously validated instruments, but in some cases, there was no pre-existing instrument and so related literature was drawn upon to develop a measure. The survey comprised several parts, four of which are relevant to this report: (1) sense of belonging, (2) perceived competence, (3) social connectedness, and (4) influence of learning opportunities on sense of belonging. The first three parts include instruments that collect data on interval-level numerical variables (i.e., sense of belonging, perceived competence, and social connectedness), and the fourth part comprised one question which collected qualitative data. Each part and its corresponding instrument (when applicable) is further described in the following sections.

Sense of Belonging

The major construct of interest in this study is students' sense of belonging in the context of their Calculus class. Good et al.'s Mathematical Sense of Belonging (MSoB) instrument (2012), which was designed to measure students' sense of belonging to the mathematics community, was used to collect data on students' sense of belonging. This instrument consists of 28 Likert items that measure five components of sense of belonging (Acceptance, Affect, Trust, Desire to Fade, and Membership) identified from a factor analysis. Each item was preceded by the phrase, "When I am in a math setting" and was measured on a 6-point Likert scale (1=*Strongly Disagree*, 6=*Strongly Agree*) to avoid dichotomous and neutral responses. Scale values were reverse-coded as necessary so that smaller values indicate lower sense of belonging and larger values indicate higher sense of belonging.

Perceived Competence

Rainey et al. (2018) describe perceived competence (in the context of being a STEM major) as feeling "like one understands major-related material or receives good grades in major-related courses" (p. 7). Since the focus of this study is narrowed from broader STEM to mathematics, a search was conducted for instruments that would measure students' perceived competence in a particular content area (e.g., mathematics). Wigfield and Eccles (2000) developed an Ability Beliefs and Expectancy instrument as part of their Expectancy-Value model of achievement motivation, where they conceptualize ability beliefs as the individual's perception of his or her current competence in a given domain (i.e., aligning with others' conceptualizations of perceived competence rather than task self-efficacy). This measure contained five items. Additionally, the Factors Influencing College Success in Mathematics (FICSMath) instrument contains a Competence/Performance component (Cribbs et al., 2015). This component contains four items. These two instruments were combined to measure students' perceived competence in their Calculus class and adapted each item to address students' perceived competence in mathematics. Items were measured on a 6-point Likert scale to avoid dichotomous and neutral responses. Smaller scale values indicate lower perceived competence and larger values indicate higher perceived competence.

Social Connectedness

Rainey et al. (2018) describe interpersonal relationships as feeling "socially connected with peers and/or faculty members, and possibly sharing common interests with peers, versus lacking social connection with peers and feeling socially different or like they do not fit in" (p. 7). In searching for an instrument that would measure students' perceptions of their relationships they have with both their instructor and their classmates, instruments measuring instructor-student and student-student rapport (Frisby & Martin, 2010), peer and faculty support (Hoffman et al., 2003), teacher-student and student-student relationships (Wanders et al., 2019), and classroom connectedness (Dwyer et al., 2004; Maloney & Matthews, 2000) were found. In reviewing these instruments, there were two priorities in mine – maintain fidelity to Rainey et al.'s definition of interpersonal relationships while keeping this portion of the survey a reasonable length (i.e., under 20 items). As written, none of the aforementioned instruments fit within these constraints, and so a mix of items from these existing instruments were selected, some without adaptation and some with adaptation. Items were measured on a 6-point Likert scale to avoid dichotomous and neutral responses. Smaller scale values indicate lower social connectedness and larger values indicate higher social connectedness.

Influence of Learning Opportunities on Sense of Belonging

This portion of the survey asked students to respond to the prompt: "Choose one of the four classroom activities you experienced in class (traditional lecture, interactive lecture, group work, or individual work), and describe how/why this activity has or has not impacted your sense of belonging in math." The four classroom activities students could choose from were determined based on activities known to be used in the course. The activities were defined for students within the survey as follows: traditional lecture (i.e., the instructor does all the talking while students listen/take notes), interactive lecture (i.e., students participate by sharing their ideas/questions and responding to the

instructor's questions), small group work (i.e., students are asked to work on problems with their group members during class time), and individual work (i.e., students are asked to work independently on problems during class time without discussing the problems with their group members). Students first selected a classroom activity from a drop-down menu, and then described its impact (or lack thereof) on their sense of belonging in an open-ended response box.

Data Analysis

For this report, only responses from participants who completed both surveys and who self-identified as women were included. Both quantitative and qualitative analyses of these participants' survey responses were conducted. Within the quantitative strand, to investigate changes in women's sense of belonging, perceived competence, and social connectedness, each student's mean score was calculated for each construct and then these means were averaged to determine the overall mean for the whole sample at each time point. A repeated-measures ANOVA was conducted to determine if there were significant differences within each construct across Week 1 and Week 7.

To investigate the influence of the learning opportunities on students' sense of belonging, first the frequencies of each learning opportunity that students chose were calculated. Then their open-ended responses were clustered by learning opportunity and each cluster of responses was read through multiple times, and themes that emerged were recorded. Open-ended responses were coded using theory-guided content analysis, with the intention of extending existing theory around what types of things contribute to students' sense of belonging. Preliminary codes that were planned to be used were *social*, *academic*, and *learning environment*, and data that could not be coded with these preliminary codes were identified and analyzed to determine whether they represented a new category or a subcategory of one of the preliminary codes. Each code was binary (i.e., the code either applied or did not), and each response could be assigned multiple codes. To achieve reliability, 10% of the responses were coded with two colleagues not involved in the study. Together 88% interrater reliability was achieved. Once reliability was achieved, the author coded the remaining responses.

Results

First, quantitative results on women's sense of belonging, perceived competence, and social connectedness at Week 1 and Week 7 of the semester are presented. Then major themes from students' open-ended responses describing the impact of the learning opportunities on their sense of belonging are described.

Changes in Women's Sense of Belonging, Perceived Competence, and Social Connectedness

Analyses of women's responses to the first survey administered in Week 1 of the semester indicate that they came in with a moderately high sense of belonging, perceived competence, and social connectedness. Participants' responses to the survey administered during Week 7 of the semester indicated significant increases in all three constructs: sense of belonging (F[1,45]=44.906, p<.001, MSE=.216, partial eta squared=.499), perceived competence (F[1,45]=5.702, p=.021, MSE=.210, partial eta squared=.112), and social connectedness (F[1,45]=16.518, p<.001,

MSE=.306, partial eta squared=.269) (See Table 1.). The fact that students' sense of belonging and social connectedness started out moderately high and then increased significantly with a large effect size (Cohen, 1988) is noteworthy.

Table 1

Women's sense of belonging, perceived competence, and social connectedness means.

	Week 1	Week 7	Cohen's *d*
Sense of Belonging	3.9049	4.5543***	.79
Perceived Competence	3.7147	3.9429*	.29
Social Connectedness	4.3028	4.7717***	.76

Note: For each of the three measures, the minimum score was 1 and the maximum score was 6. Asterisks are used to denote the *p*-values (* for $p<.05$, ** for $p<.01$, and *** for $p<.001$ significance levels).

Women's Perceptions of the Influence of the Learning Opportunities on their Sense of Belonging

When asked to select a classroom activity for which they have most to say when thinking about their sense of belonging in math, a resounding majority of women (91%) selected either group work (N=21) or interactive lecture (N=21). Only 9% of participants selected traditional lecture (N=2) or individual work (N=2). Given this, the qualitative analyses focused on on women's reports about group work and interactive lecture.

While responses were initially expected to be coded based on social and academic factors and learning environment, it became clear that a more obvious overarching theme emerged from students' responses: *interaction*. Eighty-eight percent of responses articulated that interacting during class via group work (N=20) and interactive lecture (N=17) contributed to their sense of belonging. The interactions described were mostly academic interactions, while others were social, though both played a role in supporting students' sense of belonging.

Responses were coded as *academic interactions* (N=30) when the student mentioned something they value about interactions related to their understanding of the material or their learning. For example, one woman responded, "Getting the whole class involved allows me to actually participate and learn the material." Since there were so many responses within this category, these responses were coded further and they mostly fell into subcategories based on the types of academic interactions students described – seeking/offering help (N=7) and exchanging ideas with each other (N=19). Responses coded as *social interactions* (N=10) were responses in which students mentioned valuing getting to know their classmates or forming relationships with them. For example, one woman responded, "[Interactive lecture] has tied me closer to my classmates." There were a few instances (N=7) in which students mentioned "interactions" but in too vague a way to determine the context (i.e., academic or social) of the interactions (e.g., "allows me to interact with my classmates"). These responses were coded as *interaction – other*, but still indicate that when considering their sense of belonging, the student places some value on being able to interact with others during class.

The academic interactions women described mostly had to do with seeking/offering help and exchanging ideas with their classmates. They seemed to like being able to ask their groupmates for help when something was confusing. One woman explained that during group work, "If I or one of us doesn't immediately understand a problem, usually one of us always has an idea and is willing to share and help the rest of us." While asking for help might feel uncomfortable, several students explicitly mentioned feeling comfortable enough with their groupmates to ask for help; one even described their group dynamic as nonjudgmental:

> Group work has helped me a lot. It gave me new friends with whom I am very much comfortable in sharing my ideas, helping them or seeking help from them. They don't judge me and I feel welcomed every time.

Similarly, in reference to interactive lecture, another student said, "Having interactive lecture allows me to collaborate with those around me and I feel more comfortable asking questions." These students make it clear that they feel comfortable enough to seek the help they need during both group work and interactive lecture, and that this positively impacts their sense of belonging. On the flip side, some women reported that providing help to their peers supported their own sense of belonging. In the words of one student, "Group work has impacted my sense of belonging in math as I am able to help my classmates as well as interact with them to help with my learning."

Women also reported that the ability to exchange ideas and work through problems together, either in groups or as a class, impacted their sense of belonging. In reference to group work, one student expressed that being able to bounce ideas off each other made her feel included. Another student explained that "working on problems with others in class gives a good opportunity for students to see other perspectives and descriptions on how to solve problems. Small group work has helped me learn a lot better." This idea of seeing multiple perspectives was important for others as well, both as a way to better understand the material and also as a way to see how well others were understanding the material. Another student said in reference to interactive lecture, "I would say interactive lecture is the most helpful because I get to hear what other people say and if they are struggling on the same things as me." Several students found value in hearing wrong answers shared with the class. According to one student:

> The interactive lectures make the class feel more inclusive because even wrong answers actually end up helping a lot of people because a lot of us may have also had the same mistake/thought process but didn't want to speak up/ask.

Additionally, some students described feeling a sense of solidarity with their classmates as a consequence of hearing others' ideas be shared. According to one student, "[Group work] has had the most positive impact on my sense of belonging in math because going over how we got an answer with my groupmates makes me feel like we're all in the same boat." Not only did students describe the benefits of hearing others' ideas, but they also felt comfortable sharing their own ideas. One student commented:

> Group work makes me feel more comfortable participating because I get anxious about answering questions in front of the whole class. I can share ideas with people I've grown to be comfortable and friendly with without a fear of rejection.

Students' descriptions of the social interactions typically arose in the context of group work (N=9), as this was a ripe opportunity for students to work closely with one another and thus get to know each other. Most responses that were coded as social interactions were also coded as academic interactions (N=8). For instance, in some cases, the student implied that the social interactions made them feel comfortable participating in the academic interactions. Recall the one student who said:

> Group work makes me feel more comfortable participating because I get anxious about answering in front of the whole class. I can share ideas with people I've grown to be comfortable and friendly with without having a fear of rejection.

Here we see that the social connection with her groupmates contributed to her participation in academic interactions.

Discussion and Implications

Undergraduate women often leave their STEM majors after taking Calculus, and research has identified low sense of belonging as a key reason for their departure. This study aimed to explore both the malleability of women's sense of belonging and its contributors, and the role that active learning opportunities might play in supporting women's sense of belonging. While the design of this study does not allow for causal claims, findings indicate that women in the IC course experienced greater sense of belonging, perceived competence, and social connectedness over the course of the first half of the semester, and attribute their sense of belonging to particular active learning opportunities they experienced in the IC course.

It is promising that women's sense of belonging, perceived competence, and social connectedness all increased significantly between Week 1 and Week 7 of the semester. This study did not investigate the amount of influence each of perceived competence and social connectedness holds on sense of belonging, but the fact that all three constructs behaved similarly does not rule out the existence of some influential relationship among them. Further study is needed here, as this would inform decisions on where to focus efforts toward supporting women's sense of belonging.

It is interesting that women reported such a high sense of belonging and social connectedness during the first week of the semester. The high social connectedness could be due in part to the fact that students sit in groups starting on day one of the semester. Perhaps the immediate expectation of group work and collaboration inflated their initial perception of social connectedness. In turn, an inflated sense of social connectedness could have inflated their sense of belonging given what we know about the relationship between these two constructs.

The qualitative findings from this study provide several implications for undergraduate STEM instructors. When asked to choose an activity and describe how it impacted their sense of belonging, the women in this study overwhelmingly chose to talk about interactive lecture and group work. This may imply that they value the characteristic that sets these learning opportunities apart from traditional lecture and individual work – interaction with their classmates and instructor. This was confirmed in their descriptions of how these activities impacted their sense of belonging. A large majority of students (88%) described the ways in which the interactions they engaged in via interactive lecture and

group work impacted their sense of belonging. They mostly spoke about academic interactions like giving and seeking help and exchanging ideas. But it was not only that these interactions helped them learn and understand the material; much of the impact came from the way that these interactions made students feel – comfortable. Students described feeling comfortable asking for help and sharing their ideas and they spoke about feeling "in the same boat" as their classmates. Additionally, students implicitly described the ways in which the learning opportunities supported both their perceived competence and social connectedness. They reported that interactive lecture and group work enabled them to better understand the material by hearing multiple viewpoints (whether they were correct or not), demonstrate their understanding by providing help to their classmates, see that others also struggle and are at the same pace as they are, and feel comfortable sharing their own ideas and seeking help from their classmates. These findings suggest that not only was sense of belonging impacted by the interactive learning opportunities, but perceived competence and social connectedness may have also been influenced. Again, further research is needed to characterize the influential relationship among perceived competence, social connectedness, and sense of belonging, but it is promising to see that interactive learning opportunities like interactive lecture and group work are supporting these three constructs for the women taking IC.

References

Anderman, L. H. (2003). Academic and social perceptions as predictors of change in middle school students' sense of school belonging. *The Journal of Experimental Education, 72*(1), 5–22. https://psycnet.apa.org/doi/10.1080/00220970309600877

Antonio, A. L., Chang, M. J., Hakuta, K., Kenny, D., Levin, S., & Milem, J. F. (2004). Effects of racial diversity on complex thinking in college students. *Psychological Science, 15*(8), 507– 510. https://doi.org/10.1111/j.0956-7976.2004.00710.x

Boaler, J. (1997). Reclaiming school mathematics: The girls fight back. *Gender and Education*, *9*(3), 285–305. https://doi.org/10.1080/09540259721268

Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom.* School of Education and Human Development, George Washington University.

Carmichael, S. G. (2017). Women dominate college majors that lead to lower-paying work. Retrieved from Harvard Business Review website: https://hbr.org/2017/04/women-dominate-college-majors-that-lead-to-lower-paying-work

Chamberlain, A. (2017). The pipeline problem: How college majors contribute to the gender pay gap. Retrieved from Glassdoor website: https://www.glassdoor.com/research/app/uploads/sites/2/2017/04/FULL-STUDY-PDF-Gender-Pay-Gap2FCollege-Major-1.pdf

Chen, X. (2013). *STEM attrition: College students' paths into and out of STEM fields (NCES 2014-001).* National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc. https://doi.org/10.4324/9780203771587

Cole, D. A. (1991). Change in self-perceived competence as a function of peer and teachers evaluation. *Developmental Psychology, 27*(4), 682-688. https://doi.org/10.1037/0012-1649.27.4.682

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed.). SAGE Publications.

Cribbs, J. D., Hazari, Z., Sonnert, G., & Sadler, P. M. (2015). Establishing an explanatory model for mathematics identity. *Child Development, 86*(4), 1048–1062. https://doi.org/10.1111/cdev.12363

Du Bois, B. (1983). Passionate scholarship: Notes on values, knowing, and method in feminist social science. In G. Bowles & R. D. Klein (Eds.), *Theories of Women's Studies*. London: Routledge and Kegan Paul.

Dwyer, K. K., Bingham, S. G., Carlson, R. E., Prisbell, M., Cruz, A. M., & Fus, D. A. (2004). Communication and connectedness in the classroom: Development of the connected classroom climate inventory. *Communication Research Reports, 21*(3), 264–272. https://doi.org/10.1080/08824090409359988 38

Eagan, Kevin; Stolzenberg, Ellen Bara; Bates, Abigail K.; Aragon, Melissa C., Suchard, Maria Ramirez; Rios-Aguilar, C. (2015). *American Freshman: National Norms fall 2015.* Los Angeles: Higher Education Research Institute, UCLA.

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), 1–14. https://doi.org/10.1371/journal.pone.0157447

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America, 111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Frisby, B. N., & Martin, M. M. (2010). Instructor-student and student-student rapport in the classroom. *Communication Education, 59*(2), 146–164. https://doi.org/10.1080/03634520903564362

Gibbs, K. (2014, September). Diversity in STEM: What It Is and Why It Matters. *Scientific American*. Retrieved from https://blogs.scientificamerican.com/voices/diversity-in-stem-what-it-is-and-why-it-matters/

Gilligan, C. (1982). *In a different voice: Psychological theory and women's development*. Cambridge, Massachusetts: Harvard University Press.

Griffin, C. (2021). Calculus instruction and female sense of belonging. In Olanoff, D., Johnson, K., & Spritzer, S. M. (Eds.) *Proceedings of the forty-third annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (p. 1331-1335). Philadelphia, PA. http://www.pmena.org/pmenaproceedings/PMENA 43 2021 Proceedings.pdf

Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology, 102*(4), 700–717. https://doi.org/10.1037/a0026659

Hausmann, L. R. M., Schofield, J. W., & Woods, R. L. (2007). Sense of belonging as a predictor of intentions to persist among African American and white first-year college students. *Research in Higher Education, 48*(7), 803–839. https://doi.org/10.1007/s11162-007-9052-9

Hoffman, M., Richmond, J., Morrow, J., & Salomone, K. (2003). Investigating "sense of belonging" in first-year college students. *Journal of College Student Retention, 4*, 227–256. https://doi.org/10.2190/DRYC-CXQ9-JQ8V-HT4V

Hong, L., & Page, S. E. (2004). Groups of diverse problem solvers can outperform groups of high-ability problem solvers. *Proceedings of the National Academy of Sciences of the United States of America, 101*(46), 16385–16389. https://doi.org/10.1073/pnas.0403723101

Johnson, E., Andrews-Larson, C., Keene, K., Melhuish, K., Keller, R., & Fortune, N. (2020). Inquiry and gender inequity in the undergraduate mathematics classroom. *Journal for Research in Mathematics Education, 51*(4), 504–516. https://doi.org/10.5951/jresematheduc-2020-0043

Kitzinger, C., & Wilkinson, S. (1997). Validating women's experience? Dilemmas in feminist research. *Feminism and Psychology, 7*(4), 566-574. https://doi.org/10,1177/0959353597074012

Kogan, M., & Laursen, S. L. (2014). Assessing long-term effects of inquiry-based learning: A case study from college mathematics. *Innovative Higher Education, 39*(3), 183–199. https://doi.org/10.1007/s10755-013-9269-9

Lahdenperä, J., & Nieminen, J. H. (2020). How does a mathematician fit in? A mixed-methods analysis of university students' sense of belonging in mathematics. *International Journal of 40 Research in Undergraduate Mathematics Education, 6*(3), 475–494. https://doi.org/10.1007/s40753-020-00118-5

Lahdenperä, J., Postareff, L., & Rämö, J. (2019). Supporting quality of learning in university mathematics: A comparison of two instructional designs. *International Journal of Research in Undergraduate Mathematics Education, 5*(1), 75–96. https://doi.org/10.1007/s40753-018-0080-y

Larson, R., & Edwards, B. (2012). *Calculus I with precalculus: A one-year course*. Boston, MA: Brooks/Cole.

Lewis, K. L., & Hodges, S. D. (2015). Expanding the concept of belonging in academic domains: Development and validation of the Ability Uncertainty Scale. *Learning and Individual Differences, 37*, 197-202. https://doi.org/10.1016/j.lindif.2014.12.002

Maloney, T., & Matthews, J. S. (2000). Teacher care and students' sense of connectedness in the urban mathematics classroom. *Journal for Research in Mathematics Education, 51*(4), 399– 432. https://doi.org/10.5951/jresematheduc-2020-0044

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(July), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. *International Journal of STEM Education, 5*(10). https://doi.org/10.1186/s40594-018-0115-6

Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2019). A descriptive study of race and gender differences in how instructional style and perceived professor care influence decisions to major in STEM. *International Journal of STEM Education, 6*(1). https://doi.org/10.1186/s40594-019-0159-2

Rasmussen, C., Apkarian, N., Hagman, J. E., Johnson, E., Larsen, S., & Bressoud, D. (2019). Characteristics of precalculus through calculus 2 programs: Insights from a national census survey. *Journal for Research in Mathematics Education, 50*(1), 98–111. https://doi.org/10.5951/jresematheduc.50.1.0098

Rasmussen, C., & Ellis, J. (2013). Students who switch out of calculus and the reasons they leave. *Proceedings of the 35th Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*, (1975), 457–464.

Roberts, G., Kleiber, D., & Duda, J. (1981). An analysis of motivation in children's sport: The role of perceived competence in participation. *The Journal of Sport Psychology, 3*(3), 206-216.

Rosenberg, M., & McCullough, B. C. (1981). Mattering: Inferred significance and mental health among adolescents. *Research in Community & Mental Health, 2*, 163–182.

Seymour, E., & Hunter, A.-B. (Eds.). (2019). *Talking about leaving revisited: Persistence, relocation, and loss in undergraduate STEM education*. Boulder, CO: Center for STEM Learning. https://doi.org/10.1007/978-3-030-25304-2

Shapiro, C. A., & Sax, L. J. (2011). Major selection and persistence for women in STEM. *New Directions for Institutional Research, 14*(7), 5–18. https://doi.org/10.1002/ir

Stewart, J., Clegg, D., & Watson, S. (2021). *Calculus: Early transcendentals* (9th ed.). Boston, MA: Cengage.

Strayhorn, T. L. (2012). *College students' sense of belonging: A key to educational success for all students*. New York, NY: Routledge. https://doi.org/10.4324/9780203118924

Taylor, C. T., Pearlstein, S. L., Kakaria, S., Lyubomirsky, S., & Stein, M. B. (2020). Enhancing social connectedness in anxiety and depression through amplification of positivity: Preliminary treatment outcomes and process of change. *Cognitive Therapy and Research, 44*(4), 788-800. https://doi.org/10.1007/s10608-020-10102-7

Thoman, D. B., Arizaga, J. A., Smith, J. L., Story, T. S., Soncuya, G. (2014). The grass is greener in non-science, technology, engineering, and math classes: Examining the role of competing belonging to undergraduate

women's vulnerability to being pulled away from science. *Psychology of Women Quarterly, 38*(2), 246-258. https://doi.org/10.1177/0361684313499899

Tinto, V. (1975). Dropout from higher education: A theoretical synthesis of recent research. *Review of Educational Research, 45*(1), 89–125. https://doi.org/10.3102/00346543045001089

Wanders, F. H. K., van der Veen, I., Dijkstra, A. B., & Maslowski, R. (2019). The influence of teacher-student and student-student relationships on societal involvement in Dutch primary and secondary schools. *Theory and Research in Social Education, 48*(1), 101–119. https://doi.org/10.1080/00933104.2019.1651682

Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology, 25*(1), 68–81. https://doi.org/10.1006/ceps.1999.1015

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