

Longitudinal Study of Women's Sense of Belonging in Undergraduate Calculus

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Undergraduate women leave STEM majors at a higher rate than men – especially after taking Calculus I (Chen et al., 2013; Seymour & Hunter, 2019). Research identifies low sense of belonging as a major reason why women leave STEM majors (Seymour & Hunter, 2019; Shapiro & Sax, 2011). One feels a *sense of belonging* (SB) when they feel valued or accepted in an academic community, and that their contributions are valued (Good et al., 2012). Studies have shown that students' SB can be attributed to their social connectedness (SC) with the people in their class and their perceived competence (PC) in the course material (Rainey et al., 2018). Further, Rainey et al. (2019) found that students who experienced active learning reported a stronger SB. However, few quantitative studies have investigated students' SB in relation to its influencing factors. This study examines undergraduate women's SB over the course of one semester in an active learning Calculus course. I address the research questions: For undergraduate women enrolled in an active learning Calculus course, (1) How do SC and PC contribute to their SB?, (2) In what ways do their SB, SC, and PC change over the course of the semester?

This study takes place at a Mid-Atlantic research university during the Fall 2022 semester. Two sections of the active learning Calculus course were offered, with a total enrollment of 127 students. These students are typically freshmen intending to major in STEM and do not know upon enrolling that the course provides substantial active learning opportunities (primarily small-group work and whole-class discussions). To measure students' SB, SC, and PC, a survey was designed and administered to all students during Weeks 1, 7, and 14 of the semester. The survey consisted of Good et al.'s (2012) Mathematical Sense of Belonging scale, items from several scales measuring SC (Frisby & Martin, 2010; Hoffman et al., 2003; Maloney & Matthews, 2000; Wanders et al., 2019), and items from Wigfield and Eccles' (2000) Expectancy-Value scale and Cribbs et al.'s (2015) FICSMath scale to measure PC. The data set was reduced to only include participants who self-identified as women (e.g., women and trans women).

Findings indicate that both SC and PC have a significant effect on women's SB. A regression of SB on SC and PC accounted for 47% of the variance in SB at Week 1 ($F[2,46]=20.684$, $MSE=.374$, $p<.001$), 67% at Week 7 ($F[2,43]=44.145$, $MSE=.235$, $p<.001$), and 69% at Week 14 ($F[2,40]=44.522$, $MSE=.259$, $p<.001$). Interestingly, PC held greater influence at Week 1 ($\beta_{SC}=.379$, $p_{SC}=.001$; $\beta_{PC}=.492$, $p_{PC}<.001$), while SC held greater influence at Week 7 ($\beta_{SC}=.641$, $p_{SC}<.001$; $\beta_{PC}=.305$, $p_{PC}=.003$) and Week 14 ($\beta_{SC}=.655$, $p_{SC}<.001$; $\beta_{PC}=.328$, $p_{PC}=.001$). Additionally, students' SB, SC, and PC each increased significantly between Week 1 and Week 7 and plateaued from Week 7 to Week 14 (Table 1). Results from this study confirm that SC and PC hold a significant influence over women's SB. Further, women in an active learning Calculus class can experience positive changes in their SB that align with changes in their SC and PC.

Table 1. Women's Sense of Belonging, Social Connectedness, and Perceived Competence Means.

	Week 1	Week 7	Week 14	p_1	p_2
Sense of Belonging	3.9312	4.5488	4.6159	<.001	.517
Social Connectedness	4.3676	4.7735	4.8537	.001	.444
Perceived Competence	3.7591	4.0335	4.0518	.008	.855

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Research Questions & Definitions

For undergraduate women enrolled in a year-long active learning Calculus course,

1. In what ways, if any, do their **sense of belonging**, **social connectedness**, and **perceived competence** change over the course of the first semester?
2. How do **social connectedness** and **perceived competence** contribute to their **sense of belonging** at the beginning, middle, and end of the first semester?

Sense of Belonging: feeling accepted in an academic community, and that your presence and contributions are valued

Social Connectedness: feeling socially connected or similar to those around them

Perceived Competence: feeling like they understand the material or received good grades

Context

- **Setting:** Undergraduate Calculus course with frequent opportunities for students to engage in active learning via group work and whole-class discussion; 2 sections offered with 127 students total
- **Participants:** Women enrolled in active learning Calculus; mostly first-year students intending to major in STEM

Data Collection & Analysis

Data were collected during Fall 2022 from women enrolled in active learning Calculus using online surveys.

Regression was used to analyze data at each time point.

Repeated Measures ANOVA was used to analyze data across time.

Major Findings

1. Sense of belonging, social connectedness, and perceived competence...

- a) All **increased** between Week 1 and Week 7
- b) All **plateaued** between Week 7 and Week 14.

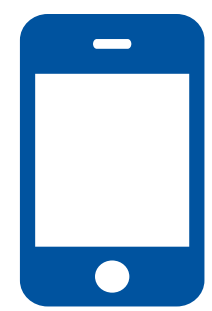
Table 1.
Women's Sense of Belonging, Social Connectedness, and Perceived Competence Means.

	Week 1	Week 7	Week 14
Sense of Belonging	3.9312	4.5488***	4.6159
Social Connectedness	4.3676	4.7735***	4.8537
Perceived Competence	3.7591	4.0335***	4.0518

Note. These results are based on students who completed all three surveys, so N=41. Asterisks are used to denote the *p*-values (* for $p < .05$, ** for $p < .01$, *** for $p < .001$ significance levels) corresponding to the significance of the difference between that time-point and the previous time-point.

2. Social connectedness and perceived competence significantly contributed to students' sense of belonging throughout the semester.

- a) **Perceived competence** held greater influence at Week 1
- b) **Social connectedness** held greater influence at Weeks 7 & 14



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Related Tables

Table 2.
Regression of Sense of Belonging on Social Connectedness and Perceived Competence.

		Sum of Squares	df	Mean Square	F	Sig.
Week 1 N=49	Regression	15.472	2	7.736	20.684	<.001
	Residual	17.204	46	.374		
	Total	32.676	48			
Week 7 N=46	Regression	20.788	2	10.394	44.145	<.001
	Residual	10.125	43	.235		
	Total	30.913	45			
Week 14 N=43	Regression	23.037	2	11.518	44.522	<.001
	Residual	10.349	40	.259		
	Total	33.385	42			

Note. Sample sizes at each week differ here because each regression was run without regard for how many participants completed multiple surveys.

Table 3.
Regression coefficients.

		Unstandardized coefficients		Standardized coefficients		t	Sig.
		B	Std. error	Beta			
Week 1 N=49	Constant	-.214	.685			-.312	.756
	Social Connectedness	.510	.148	.379		3.438	.001
	Perceived Competence	.514	.115	.492		4.467	<.001
Week 7 N=46	Constant	-.086	.500			-.172	.864
	Social Connectedness	.702	.106	.641		6.632	<.001
	Perceived Competence	.326	.104	.305		.3152	.003
Week 14 N=43	Constant	-.304	.525			-.580	.565
	Social Connectedness	.759	.109	.655		6.955	<.001
	Perceived Competence	.302	.087	.328		3.480	.001

Conclusions

- **Social connectedness** and **perceived competence** do in fact significantly influence women's **sense of belonging** in mathematics.
- The amount of influence each contributor had on **sense of belonging** was different at different time points.
- Women in an active learning Calculus class can experience positive changes in their **sense of belonging** over time.