Understanding sources of Belonging amongst upper division physics majors: Results from a sequential, explanatory mixed-methods study

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Sense of Belonging is an essential human motivation that has been shown to be a critical component of students' undergraduate careers. The current paper reports on a sequential, explanatory mixed-methods study to understand the factors that may shape Sense of Belonging amongst students during a critical semester of their studies – while taking modern physics, which is a transition course from lower- to upper-division for students intending physics majors and minors. In this sequential design, a quantitative study of students' Sense of Belonging was first conducted, with a 44-item survey (including measures of Sense of Belonging and Physics Identity) administered at the beginning and end of the semester, for three different semesters (different classes of students). After validation, we found significant gains in Sense of Belonging in one particular semester of this course. To understand why this might have happened, we conducted the second phase of this study by interviewing students who showed positive gains during that semester. The purpose of the second phase was to explore possible sources (experiences, supports, etc) that contributed to these gains. We report a comparative case analysis of three students and consider three distinct sources of improved Sense of Belonging: classroom experiences, peers, and departmental/community experiences. These results suggest hypotheses for further study in future work, and identify possible ways that educators can support physics students to gain positive Sense of Belonging during their student careers.

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I. INTRODUCTION

Despite decades of research to understand how to improve the persistence of STEM majors in higher education [1, 2], the gap between the number of intended science, technology, engineering and mathematics (STEM) majors in college and the number of actual STEM graduates has grown. Much work has rightly focused on issues related to the transition from high school to college [3] and early college STEM experiences [4], but it is relevant to understand how students move from their early to late college studies and develop lasting commitments to STEM careers. It has been understood that there is substantial development of science identities during a tertiary education [5, 6]. In a physics context, it was shown that Sense of Belonging is a contributor to physics identity and is more important to the physics identities of upper division physics majors than lower division students [7], suggesting that Sense of Belonging becomes more central for students during the course of their undergraduate studies. More broadly, Sense of Belonging has been shown to be a critical component of student academic success in a range of contexts [8, 9].

The current two-phase study seeks to understand how students' Sense of Belonging develops over the period of enrollment in an active-learning Modern Physics course, a mandatory course for physics majors and minors, usually taken the first semester of their third or junior year where they begin more advanced coursework. This course and semester has previously been shown to be critical in students' undergraduate physics careers [10], having been identified as the semester of highest risk to non-persistence in the upper division sequence. We were motivated to understand, during this critical time in an undergraduate career, if and how students' Sense of Belonging changes (if at all). For context, during the period of this study, the course was offered in an active modality, with students spending much of class time working in small groups on scaffolded activities on topics including special relativity and introductory, one-dimensional quantum mechanics. Further, students were generally co-enrolled in other upper-division physics, mathematics, and/or astronomy courses as well as non-physics STEM courses (particularly for physics minors).

II. THEORETICAL BACKGROUND

Sense of Belonging is a fundamental human motivation by which people will strive to form and maintain social connections with each other [11]. In the current work, we define sense of belonging as

> the sense of being accepted, valued, included, and encouraged by others (teachers and peers) in the academic classroom setting and of feeling oneself to be an important part of the life and activity of the class. (p. 25) [12]

Sense of Belonging has been a topic of interest in the field of education research for decades [13] which has recently grown as a focus within Discipline Based Education Research (DBER) and STEM education [14, 15]. Much of this growth has focused on adolescence and early undergraduate students [12, 14, 16–18]. Other work has examined Sense of Belonging in STEM for senior undergraduate and graduate students [18, 19]. Sense of Belonging has been shown to be associated to student persistence in physics contexts [14]. Furthermore, the relevance of Sense of Belonging for women in physics has been emphasized by Stout et al [20], who found that women who reported greater endorsement of a stereotype (that women are not good at physics) had a lower Sense of Belonging than other female peers.

However, there is less work on students' experiences in the transition from lower to upper division undergraduate studies, when many move from "introductory" to "advanced" disciplinary experiences. Prior work has found that Sense of Belonging is more important for upper division students' physics identities compared to lower division students [7]. This suggests that significant development of Sense of Belonging – in both its nature and relationship to other attitudinal constructs – occurs during the intermediate years.

III. RESEARCH QUESTIONS

In this paper, we sought to address the following research questions, which together form a sequential, explanatory mixed-methods study:

1. (Quantitative, Phase 1:) As measured by a validated pre-post survey instrument, how does students' Sense of Belonging change, if at all, over the course of a semester during enrollment in Modern Physics?
2. (Qualitative, Phase 2:) For students that exhibited increases in Belonging in their pre-post measure, what experiences (classroom, peer, or departmental/community) are identified by students as helping to explain these changes?

IV. METHODS

In Phase 1, we collected quantitative survey data pre- and post-semester at a large R1, public university. Demographics overall were about 80% Male, 20% Female, 74% Hispanic, 13% White, 6% Asian, 4% Black, 2% Other. Demographic data was not presented for individual semesters due to small N presenting anonymity concerns. The survey instrument included 44, seven-point anchored scale items assessing constructs of identity (Performance/Competence beliefs, Interest in physics, and Recognition beliefs) for both physics specifically and science generally, as well as Sense of Belonging. Salient to the current paper, the latter items probed Sense of Belonging in the classroom (6 items) and in the university (10 items). As part of the item validation, a total of 71 pre-surveys

TABLE I. Summary of final Sense of Belonging items and standardized factor loadings in a single factor.

Item	Standardized Factor Loading
I want to keep in touch with other students after this course is over.	0.717
I feel like other students in this course encourage me to do well.	0.736
I feel respected by other students in this course.	0.916
I feel like other students in this course accept me for who I really am.	0.866
I can be myself with other students in this course.	0.914
I feel supported by other students in this course.	0.828

were collected in four different semesters from individual students and, in the subsequent analysis, a total of 50 matched pre-post surveys were collected in three of these semesters from individual students (e.g. one semester only had pre-surveys). In the validation phase of the analysis, exploratory factor analysis was used as an initial exploration, followed by confirmatory factor analysis (CFA) to establish our Sense of Belonging measure. (All analyses were performed using **R** [21].) The results of the CFA indicated a single factor measuring Sense of Belonging, constructed from the 6 "classroom" measures. The standardized factor loadings from the CFA are summarized in Table I; all were significant and above 0.5 as recommended [22]. The model returned a Comparative Fit Index (CFI) of 0.956, Root Mean Square Error of Approximation (RMSEA) of 0.062, and Standardized Root Mean Square Residual (SRMR) of 0.073. These represent acceptable fit thresholds [23, 24]. With this measure established, we then performed paired t-tests on the pre- to post-semester Sense of Belonging measure to address research question 1.

In Phase 2, we used the results of the previous quantitative analysis to pursue a focused case study on students who (a) were part of a class that was found to have a statistically significant gain in Sense of Belonging (i.e., an overall gain on average in Sense of Belonging in the class) and (b) as individuals, reported a positive shift in their own Sense of Belonging (as measured by their pre-post survey responses). The goal of this second phase, as articulated by research question 2, was to understand the sources of such a shift, whether from classroom, peer, or community/departmental experiences. So, three specific students were recruited to participate in follow-up interviews 10-16 months after the end of their taking of modern physics. The interview followed a semi-structured protocol that probed each students' education history, their perceptions of their studies during the semester in Phase 1, the experiences that they felt impacted their Sense of Belonging, and their career intentions. These interviews were audio recorded, transcribed, and coded using an emergent, inductive approach for between-case comparison.

V. RESULTS

The results of the paired t-test comparing students pre- to post-semester Sense of Belonging during three semesters is summarized in Table II. In particular, during Fall 2022, students ($n = 18$) gained an average of 0.935 points (on a seven-point scale), $p < 0.01$. This quantitative shift motivated the second phase of this paper, and we used the paired responses to identify potential participants for follow-up interview.

TABLE II. Results of repeated measures t-test of Sense of Belonging and Pre/Post Averages over three semesters.

	Pre	Post	t score	p-value	Mean Change (of 7)
Spring 2022 ($n = 13$)	4.280	4.410	0.376	0.713	0.128
Fall 2022 ($n = 18$)	3.610	4.550	3.541	0.003	0.935
Spring 2023 ($n = 19$)	4.520	4.300	-0.596	0.559	0.219

In particular, three students – all women, although gender was not part of the selection criteria for this study – were interviewed 10-16 months after the completion of the semester. At the time of interview, all three were still undergraduates nearing the end of their degrees, and had reported a large positive shift in Sense of Belonging over the semester of Modern Physics. Each is reported below using the pseudonyms Michelle, Colleen, and Morgan.

Although these interviews were conducted as part of a larger study with other research goals, for purposes of the current paper, we present the results drawn from their interviews that address research question 2, focusing particularly on experiences that each interviewee identified as a reason for their shifts in Sense of Belonging. The results for each participant are described according to three major sources of Sense of Belonging we identified and labeled in the coding analysis: classroom, peer, and community/department.

A. Morgan: Engagement with core content and classroom pedagogy

Morgan identified her classroom experiences as the primary source for improvements in her sense of belonging, more so than the other two cases. She did not seek, nor receive, significant peer support during the semester of study, and did not identify departmental/community sources.

Classroom experiences: Morgan was very interested in the core content and material of the Modern Physics class. The topics of quantum mechanics taught in the course stirred many questions in her. Furthermore, in reference to the pedagogy of the course (student groups and discourse), she explained that her classes are more enjoyable if the professor showed a passion for the subject and for teaching it, believing that such motivation passes down to the students. She commented:

> ...so I felt like I was contributing a lot by asking the questions, and I was satiating my own curiosities and my own like things that felt like they were in conflict with my intuition that I enjoyed bringing up. So that's why I felt very comfortable. It was just like the reception of the professor.

Thus, her experiences were strongly tied to the professor and her engagement in learning the content, independent of her peers. She explained that she felt the most "in tune" when she was able to talk during the class discussions. She noted that the professor's receptivity to her questions satiated her curiosity and made her feel comfortable in the class.

Peer support: Although this was the semester where she met many of the physics students that would later become her friends, during this semester Morgan did not engage significantly in peer groups: she studied by herself and was very selective with who she interacted with during class time. She noted that if she was in a group that was quiet then she didn't interact with others at all. If she was in a more gregarious group of students, she would only interact if they were on topic and showing similar interest in the topic as her.

Community/department: Morgan did not identify sources for her improved Sense of Belonging from departmental or community experiences, in contrast to Colleen and Michelle (discussed below). That semester, she did not attend office hours, participate in research experiences or internships, and mostly socialized with her non-physics friends. Due to this, she did not have a good sense of the nature of the physics community. She later developed a better sense the following semester, when taking a subsequent advanced physics course.

B. Colleen: Peer engagement inside and outside the class

Colleen was a student who did not feel that her direct classroom experiences supported her improved Sense of Belonging; rather, it was the strong peer group of friends amongst physics majors who she strongly identified with. She did report some departmental/community experiences that contributed to her Sense of Belonging.

Classroom experiences: Colleen was less receptive to the engaged style of the Modern Physics class. She was not as engaged in the core content asking few questions in discussions and did not become attached to the topics of Modern Physics in and of themselves.

Peer support: Colleen socialized with other students frequently, particularly other physics majors that were interested in physics topics. It was during this course that she was able to find the friend group with whom she continued to study after the end of this course (up to the time of her interview). She explained that they appealed to her due to a combination of them being able to focus on the material as much as they would joke and have fun. These friends, she explained, had common interests with her, compared to her non-physics friends. She stated that she engaged more with her physics friends because they shared the experience and the interests of being in the major, contrasting to non-physics friends that did not understand the struggles of certain assignments. She also mentioned closeness to her friends on a personal/emotional level, emphasizing vulnerability as important for her:

> [H]aving those people, like, the same mentality. I guess, you're all kind of going through it together, and you just automatically feel closer, and, like, you can be more yourself. Especially the whole idea of most physics majors suffer the imposter syndrome. We're all suffering it together, and you have that vulnerability with each other.

Specifically, she described her friends as being open about not understanding certain materials and how they had also struggled in the same ways she had, emphasizing that they would calm her down when she felt "stupid".

Community/department: Colleen reported some influence from departmental/community experiences. She was an active participant in the weekly departmental tea time, an event for both students and faculty to engage with each other over drinks and snacks. She stated that during these events, she was able to communicate with her professors better by being able to disengage from the narrow topics of physics and discuss subjects such as sports and traveling.

C. Michelle: Research internship as a source of Belonging

Thirdly, and in significant contrast to the other two students, Michelle identified a meaningful community/department experience during the semester as having been her primary (even sole) source of improved Belonging. For context, she separately claimed that she did not have significant support from family and external friends on being a physics major, which made her question pursuing the degree during the period of study.

Classroom experiences: Michelle felt that she had been extremely *uninvolved* in the classroom. She noted that she had taken her lower division courses online during the initial years of the COVID-19 pandemic and, as a consequence, felt extremely shy in her first in-person class since that period. She did not feel confident asking questions or engaging with in-class discussions. At the time of Modern Physics, she was very worried about her "fundamentals in physics" and how it might impact her studies:

> I'm the type of person that, if I don't have, a good, solid background in something, and I keep

continuing doing that said something, I don't want to do it anymore.

Her lack of feeling confident in understanding the fundamentals prior to entering Modern Physics, confounded with external issues, made for what she considered one of the worst semesters in her college career, despite the large gain in Belonging she reported.

Peer support: Being very shy, Michelle did not report interacting with any of the other students in the class. She was not able to form a friend group that semester. In the lab course that she was required to retake the semester after Modern Physics, she connected to two students that would become her peer group because of personality, race, economic background, and similar experiences in courses. But in the context of the current study, she did not report contributions of peer support to her Belonging.

Community/department: During the semester of this study, Michelle applied to a nuclear physics research opportunity offered to undergraduates at the university. This allowed interns to choose to work with different professors in their existing research projects. She chose to intern with a professor that she felt that she got along with on a personal level and became a part of his team. She was able to discuss physics and ask questions about topics that she felt she needed to improve on in comfort (as opposed to being uncomfortable doing the same in class). Michelle strongly felt that working with this particular professor and his graduate students during the semester motivated her to keep pursuing physics. She continued the internship and presented the work at a physics conference, where she received a top presenter award.

VI. DISCUSSION

From the mixed results of Phase 1, we identified three cases – students who were part of a semester that had significant gains in Sense of Belonging and who themselves reported individual gains over the initial study period. Upon subsequent interview after the end of the semester, each reported distinct sources for these gains from their classroom experiences, peer support, and other community/departmental experiences.

There are some similarities between the cases: Morgan and Michelle were heavily influenced by their relationship with a professor (although different professors and in different contexts). Morgan's relationship was in the context of the Modern Physics class and was associated to the pedagogy utilized by the professor (e.g. classroom management and receptiveness to questions and discourse about core content). Michelle's professor relationship was specifically related to her concurrent research internship, and the support and mentoring she received from the professor and his research group. She saw benefit and comfort in these interactions because of the one-on-one time she received and the support for her prior knowledge that she felt was needed to succeed in her classes.

Colleen and Morgan were influenced by their peers in the class. Colleen explained that she had met the physics students that became her friends, acknowledging their shared interests and personalities. Morgan's interactions with other students was positive only when they where also interested in the classroom topics and were actively engaged with it in class. Her experience did not prioritize personality and common interests as Colleen did. Despite these differences, both reported that students they met during Modern Physics ultimately became their close group of peers in later semesters.

Despite the similarities, each case presented a distinct emphasis on the primary source for their improved Sense of Belonging. Morgan's strongest influence came directly from how the professor presented the material and allowed her to contribute to the class by asking questions during discussion. Colleen's primary source of Belonging came from finding a group of students that she felt comfortable with socializing, studying, and commiserating with. Michelle's primary influence came from outside the classroom entirely and allowed her to overcome a self-perception of a lack of preparedness and shyness in engaging with peers.

The results of this two-phase study indicate the complexity of Sense of Belonging but present some reasons for optimism amongst educators: students may be able to drawn on a variety of experiences in developing their own Belonging. Different students with different needs may be able to satiate these needs in a variety of ways, and educators need not insist that "one size fits all" in supporting students to develop lasting commitments to their major and career. In this case, three students – all coincidentally women – who each reported large gains in Sense of Belonging during a semester of studying Modern Physics (amongst other advanced courses) actually identified widely varying reasons for this shift, in ways that contrast in interesting ways. Physics educators may serve their students well by offering a multiplicity of resources and/or opportunities for students to find sources for growth in Belonging, both inside and outside the classroom. Moreover, it is clear that even students who do not respond to one particular experience (e.g. those that do not strongly identify with a physics topic or class) can draw on other sources for support and increased Belonging, so educators should be mindful to ensure that such sources are made available to students.

A limitation of this work is the size of the student community at the institution of study: only $\sim 20-25$ students advance to Modern Physics each semester. Though not unusual for many physics programs, this is a limitation on the statistical power of Phase 1, and a future study could address this by collective larger data. Further, in the current work, we focused on students who reported large individual gains in Sense of Belonging (during a semester in which there were significant gains), but did not consider students who reported decreases in Belonging. While less common in this case, it would be interesting in future work to identify the reasons for decreases in Belonging to help identify classroom, peer, departmental/community or other experiences that need attention in order to help undergraduate students progress towards lasting commitments to their STEM careers.

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