Collaboration Affects Student Learning and Sense of Belonging in Introductory Biology

Sayali Kukday; Iowa State University, Ames, IA
Patricia Habersham; College of William & Mary, Williamsburg, VA
J. Elizabeth Richey; Carnegie Mellon University, Pittsburgh, PA

Subject/Problem

Introductory biology courses serve as an important gateway for students pursuing a variety of STEM careers. Fewer than 40 percent of students who intend to pursue STEM majors ultimately complete STEM degrees, and women and Persons Excluded due to their Ethnicity or Race (PEERs; Asai, 2020) are disproportionately underrepresented among STEM graduates (PCAST, 2012) and more likely to report low feelings of belonging in STEM courses (Gonzales et al., 2002; Stewart, 2013). This low sense of belonging may ultimately contribute to underserved students' attrition in the field (Perez et al., 2014). Therefore, interventions that support students' sense of belonging are critical to improve outcomes for undergraduate students in biology, particularly for supporting the success of students most at risk for leaving the major.

The importance of belonging in education has become increasingly apparent during the COVID-19 pandemic, as students and educators transitioned to fully virtual learning settings. Increased use of online learning combined with a lack of in-person connections has led to an increased sense of isolation among students (Son et al., 2020), amplifying the experiences of many students—particularly PEERs—before the pandemic (Dortch & Patel, 2017). In contrast, a sense of belonging in an academic context contributes to student success and motivation (Freeman et al., 2007; Strayhorn, 2012). When students feel like they belong in the classroom, they experience greater academic achievement, feelings of cognitive competence, academic motivation, and commitment to school. Belonging in academic settings is defined not only as a sense of inclusion, positive relations, and involvement, but also feeling like one's skills and interests are valued or even integral to the system (St-Amand et al., 2017).

Diversity and inclusion are increasingly prioritized at universities but enrolling a larger number of PEERs and women does not translate into more STEM degrees and careers for underrepresented students (White et al., 2006). Addressing students' feelings of belonging in STEM courses could be one pathway to achieve greater diversity in STEM disciplines. A sense of belonging is particularly important for students at heightened risk of experiencing stereotype or identity threat in academic contexts (Rainey et al., 2018), and interventions aimed at improving belonging have resulted in improved achievement and retention for them (Cook et al., 2012).

The field of biology education research has explored collaborative processes as a means of supporting learning outcomes. In response to several national agencies calling for change in undergraduate STEM education (AAAS, 2015), many college biology professors have embraced the call to action by incorporating active learning in their courses (Weir et al., 2019). Among active learning techniques, collaborative learning has shown learning gains in introductory biology courses (Armstrong et al. 2007). Although there is a large body of research on collaborative learning, less is known about the impact of collaboration on student affect, especially in undergraduate biology courses (Trujillo & Tanner, 2014). One previous study found that introducing a variety of active learning strategies, including collaboration, supported students' feelings of belonging (Ballen et al., 2017), but prior research that empirically tested the

effects of collaboration, specifically, on students' sense of belonging in college STEM courses is limited. We hypothesize that collaborative learning fosters experiences that are conducive to belonging; specifically, working with classmates on academic content can help students make connections, find common ground, and feel recognized and valued by their peers. We strive to contribute to the literature by studying the impact of collaboration on students' sense of belonging in addition to their learning in large-enrollment introductory biology courses.

In this research, we aimed to empirically compare the effects of completing targeted course activities collaboratively versus individually on students' sense of belonging in the course and academic performance. We asked the following research questions:

1. Does collaboration affect students' sense of belonging in an introductory-level biology course relative to students who complete the same work individually?
2. Does collaboration affect student learning in an introductory-level biology course relative to students who complete the same work individually?

Design/Procedure

During Fall 2020, we conducted an experiment testing the social and cognitive impact of collaboration on student learning in online asynchronous introductory biology courses at two institutions (Datasets 1 & 2). At the beginning of the semester, the instructors used randomization methods to divide the classes such that half the students in the course worked in teams and the other half worked individually. We followed a between-subjects crossover design and switched students to the other condition partway through the semester so that all students could gain the same experiences in the same course; since effects of collaboration in the first half of the semester could carry over for students who completed the second half of the course individually, we focused our analyses on data collected during the first half of course (i.e., before and after completing the first pair of activities as teams or individuals). A total of 581 students consented to participate in the study.

Students completed four activities working individually or in teams assigned by the instructor based on responses to a background survey completed during the first week to gather information about demographics, sense of belonging, self-efficacy, mastery achievement goals, and prior team experiences. These data served as our pre-semester baseline for the respective constructs. Students also completed a content knowledge pre-assessment to establish a baseline for learning concepts covered in course activities. They completed two activities either individually or in a team and two more after switching conditions. After students completed both activities in their assigned condition, we measured changes in each construct through a post-activity survey. For students assigned to the team condition, we also asked about team experiences while engaging in course activities. Our analyses focused on the first group of students assigned to teams, which allows for comparison to a group of students that had completed all work up to that point as individuals.

In Spring 2021, we repeated the experiment in the online asynchronous introductory biology course at one institution. To better understand the effects of semester-long collaboration, we used a quasi-experimental design with all students in one section working in assigned teams ($n = 100$) while all students in a second section worked individually ($n = 50$) for the entire duration of the semester (Dataset 3).

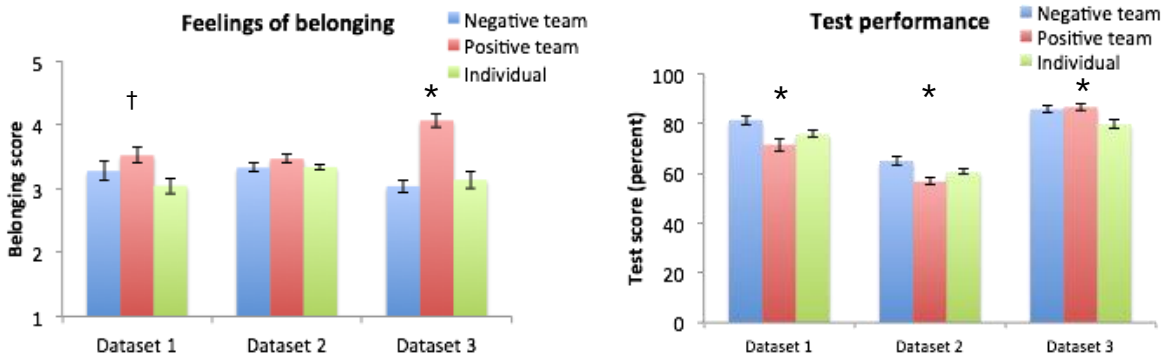
To understand the impact of team experience, we conducted a median split based on the team experience measure to create "negative experience" and "positive experience" groups. We compared students who worked individually, those who worked in teams and reported a negative

experience, and those who worked in teams and reported a positive experience. We assessed post-collaboration measures while controlling for the respective baseline measures.

Analysis and Findings

***Finding 1*:** Across all three datasets, students who reported positive team experiences tended to show higher levels of belonging than students who worked individually or those who reported negative team experiences. Results were marginally significant in Dataset 1, $F(2, 114) = 2.62$, $p = .077$, and significant in Dataset 3, $F(2, 115) = 16.33$, $p < .001$ (Figure 1). The effect was not significant in Dataset 2, $F(2, 365) = 0.25$, $p = .78$.

***Finding 2*:** Students who reported negative team experiences performed significantly better on the test following their collaborative experiences on the first set of activities (Datasets 1 and 2) in Dataset 1, $F(2, 131) = 4.17$, $p = .018$, and Dataset 2, $F(2, 378) = 6.69$, $p = .001$. In Dataset 3, students in both team conditions performed significantly better on the last test before the final exam than students working individually, $F(2,116) = 6.69$, $p = .002$ (Figure 2).



Figures 1 and 2: Team experience and belonging (left) and team experiences and test performance (right). * indicates $p < .05$ and † indicates $p < .10$.

Consistent with our predictions, a positive team experience generally led to greater feelings of belonging. The impact appeared to grow over longer team experiences, as the effect only reached significance in Dataset 3. Unexpectedly, a *negative* team experience had a significant, positive effect on exam performance in Datasets 1 and 2, while working in a team had a positive effect regardless of experience in Dataset 3. It may be that productive teamwork takes time to develop, and that those reporting initially negative experiences were actually engaged in more productive conflict and sense-making. In a preliminary effort to understand team experiences, we include example student comments:

Positive team experience example: *"This semester my experience with teamwork has been fairly positive. I find it very helpful to be able to discuss answers to questions in the quizzes as well as the activities because it often helps me to correct erroneous areas of thinking on my part but also to confirm that I am on the right track in other areas. Especially during a semester where most of the material is learned remotely, I enjoy being able to work in teams so as to feel more like I am a part of the class."*

Negative team experience example: *"So far, I feel that it can be a hit-or-miss experience. Sometimes, it is a little bit frustrating when some teammates are not participating at all.*

Additionally, sometimes it can slow the process of learning because we must stop and explain concepts to those who don't understand them. However, obviously the flip side is that when I don't understand topics, I have classmates who can help me. Thus, I understand the benefits of team work, but overall I feel that learning alone is more effective for me."

Our future directions include qualitatively analyzing students' short-answer responses about their team experiences and the activities they completed as teams or individuals to better understand differences in student perceptions about team dynamic and how they learned.

Contribution

Our research provides promising initial evidence that collaboration can improve students' sense of belonging, which is an important predictor of learning and retention in STEM (Freeman et al., 2007; Strayhorn, 2012). Although prior research has emphasized the types of collaboration that improve learning, we tested these principles in a new way by systematically examining belonging through collaborative learning in large-enrollment introductory biology courses. Understanding how collaboration impacts sense of belonging, a factor that disproportionately affects women and PEERs in STEM, is a critical step toward supporting a diverse and equitable STEM workforce. While roughly half of our participating students identified as women, relatively few students identified as PEERs (less than 15% across samples). Given that a sense of belonging can be a particularly powerful predictor of learning outcomes among PEERs, our future efforts will include recruitment at universities with larger PEER enrollment.

Many students value collaboration as a means of learning how to work with others and developing relationships with classmates (Burdett & Hastie, 2009). Engaging in collaborative learning activities can increase students' comfort with collaborative skills (Yazici, 2004) and their positive feelings toward group work (Payne & Monk-Turner, 2006). Collaboration in distance learning courses can also increase satisfaction and perceptions of social presence in the course (So & Brush, 2007).

General Interest

Our research examines collaboration and sense of belonging in introductory biology, which is one of the earliest college experiences for many undergraduate students and can thus have a large impact on students' trajectories in STEM disciplines. Our work identifies a relatively simple instructional intervention to increase students' experiences of belonging while achieving better course learning outcomes. If collaboration bolsters belonging, it could serve as an important instructional tool for supporting achievement and increasing retention of PEERs, women, and first-generation college students in the sciences.

References Cited

AAAS (American Association for the Advancement of Science) (2015). Vision and Change in Undergraduate Biology Education: Chronicling Change, Inspiring the Future. Washington, DC: AAAS.

Armstrong, N., Chang, S. M., & Brickman, M. (2007). Cooperative learning in industrial-sized biology classes. *CBE Life Sciences Education, 6*(2), 163-171.

Asai, D. J. (2020). Race Matters. *Cell, 181*(4), 754-757.

Ballen, C. J., Wieman, C., Salehi, S., Searle, J. B., & Zamudio, K. R. (2017). Enhancing Diversity in Undergraduate Science: Self-Efficacy Drives Performance Gains with Active Learning. *CBE—Life Sciences Education, 16*(4), ar56.

Burdett, J., & Hastie, B. (2009). Predicting satisfaction with group work assignments. *Journal of University Teaching & Learning Practice*, *6*(1), 62-71.

Cook, J. E., Purdie-Vaughns, V., Garcia, J., & Cohen, G. L. (2012). Chronic threat and contingent belonging: protective benefits of values affirmation on identity development. *Journal of Personality and Social Psychology, 102*(3), 479-496.

Dortch, D., & Patel, C. (2017). Black undergraduate women and their sense of belonging in STEM at predominantly White institutions. *NASPA Journal About Women in Higher Education, 10*(2), 202-215.

Freeman, T. M., Anderman, L. H., & Jensen, J. M. (2007). Sense of belonging in college freshmen at the classroom and campus levels. *The Journal of Experimental Education, 75*(3), 203-220.

Gonzales, P. M., Blanton, H., & Williams, K. J. (2002). The effects of stereotype threat and double-minority status on the test performance of Latino women. *Personality and Social Psychology Bulletin*, *28*(5), 659-670.

Payne, B. K., & Monk-Turner, E. (2006). Students' perceptions of group projects: the role of race, age, and slacking. *College Student Journal, 40*(1), 132-139.

Perez, T., Cromley, J. G., & Kaplan, A. (2014). The role of identity development, values, and costs in college STEM retention. *Journal of Educational Psychology, 106*(1), 315-329.

President's Council of Advisors on Science and Technology. (2012). Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Washington, DC: U.S. Government Office of Science and Technology

Rainey, K., Dancy, M., Mickelson, R. et al. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. *International Journal of STEM Education, 5*(10), 1-14.

So, H. J., & Brush, T. A. (2008). Student perceptions of collaborative learning, social presence and satisfaction in a blended learning environment: Relationships and critical factors. *Computers & Education*, *51*(1), 318-336.

Son, C., Hegde, S., Smith, A., Wang, X., & Sasangohar, F. (2020). Effects of COVID-19 on college students' mental health in the United States: Interview survey study. *Journal of Medical Internet Research*, *22*(9), e21279.

St-Amand, J., Girard, S., & Smith, J. (2017). Sense of belonging at school: Defining attributes, determinants, and sustaining strategies. *IAFOR Journal of Education*, *5*(2), 105-119.

Stewart, D. L. (2013). Racially minoritized students at US four-year institutions. *The Journal of Negro Education, 82*(2), 184-197.

Strayhorn, T. L. (2012). *College students' sense of belonging: A key to educational success for all students*. Routledge.

Trujillo, G., & Tanner, K. D. (2014). Considering the role of affect in learning: monitoring students' self-efficacy, sense of belonging, and science identity. *CBE Life Sciences Education, 13*(1), 6–15.

Weir, L. K., Barker, M. K., McDonnell, L. M., Schimpf, N. G., Rodela, T. M., & Schulte, P. M. (2019). Small changes, big gains: A curriculum-wide study of teaching practices and student learning in undergraduate biology. *PLoS ONE 14*(8), e0220900.

White, J. L., Altschuld, J. W., & Lee, Y. F. (2006). Persistence of interest in science, technology, engineering, and mathematics: A minority retention study. *Journal of Women and Minorities in Science and Engineering*, *12*(1), 47-64.

Yazici, H. J. (2004). Student perceptions of collaborative learning in operations management classes. *Journal of Education for Business*, *80*(2), 110-118.