"It made me feel like a bigger part of the STEM community": Incorporation of Learning Assistants Enhances Students' Sense of Belonging in a Large Introductory Biology Course

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ABSTRACT

Large introductory science courses are a particularly important and challenging target for creating inclusive learning environments. In this study, we examined the impact of incorporating learning assistants (LAs) on the learning environment in an introductory biology course taught with two different structures: an in-person lecture with intermittent active-learning components and an online setting taught with a flipped instructional approach. Using a survey that measured sense of belonging in a single class, we found that students in sections with LAs reported greater sense of belonging than students in sections without LAs in both class structures. Further, student focus groups revealed that LAs promoted learning and engagement in the class by answering questions and providing clarity; allowing more use of active- and interactive-learning structures; and serving as accessible, approachable, and immediate sources of help. Student responses also indicated that LAs promoted a sense of belonging in science, technology, engineering, and mathematics (STEM) by decreasing feelings of isolation, serving as inspirational role models, clarifying progression through the STEM educational system, and helping students become more engaged and confident in their STEM-related knowledge and skills. These findings indicate that LAs can support multiple elements of inclusive STEM learning environments.

INTRODUCTION

Creating a welcoming and inclusive environment in the college classroom remains a persistent challenge, especially in courses in which one instructor is leading a room of 200+ students. Many interventions are focused on a switch from traditional lecture to more highly structured courses that incorporate preclass assignments, in-class engagement activities, and/or postclass review assignments (Haak *et al.*, 2011; Eddy and Hogan, 2014; Gavassa *et al.*, 2019) and that increase use of active-learning approaches (Smith *et al.*, 2011; Tsaushu *et al.*, 2012; Theobald *et al.*, 2020). These pedagogical changes can increase learning gains and reduce performance gaps between underserved and well-represented groups (Haak *et al.*, 2011; Eddy and Hogan, 2014; Freeman *et al.*, 2014; Theobald *et al.*, 2020), although it is important to acknowledge that these results are not uniform (Van Dusen and Nissen, 2019). Other interventions focus on students' psychosocial needs. For example, values affirmation interventions seek to foster students' feelings of integrity and self-worth (Jordt *et al.*, 2017), while social belonging interventions seek to frame adversities as common, shared experiences, thereby increasing student resilience in challenging

settings (Walton and Cohen, 2011; Yaeger *et al.*, 2016). Both values affirmation and social belonging interventions have been found to have positive impacts, typically measured by student performance and persistence.

In this study, we sought to foster a more inclusive learning environment through the use of undergraduate learning assistants (LAs). LAs are undergraduate students with prior experience in a course who work with an instructor(s) to help facilitate small-group discussions in the classroom (Otero *et al.*, 2010; Otero, 2015). The LA program model involves 1) LAs interacting with students during class time to foster student learning; 2) weekly course preparation meetings between LAs and course instructors to discuss the course content and share feedback; and 3) a pedagogy course seminar in which LAs learn about equitable and inclusive teaching practices, reflect on their own practice, and develop a support system to manage challenges (Otero, 2015; Otero *et al.*, 2010; Barrasso and Spilios, 2021). It is recommended that LAs receive financial compensation and do not play a role in grading.

While there has been research on the impact of LAs on differential performance among student groups as an indicator of inclusive teaching (reviewed in Barrasso and Spilios, 2021), there has been less work examining how LAs impact a more direct measure of an inclusive learning environment: students' sense of belonging. Students' sense of belonging is the feeling of being part of a group or community (Strayhorn 2019) and is an essential element for inclusion and equity. To contribute to literature on inclusive teaching and LA programs, this study examines how an LA program model fosters more inclusive environments in introductory biology, using students' sense of belonging as a key indicator.

Prior Research on LA Programs

Currently, much of the literature on LAs focuses on the positive effect that the position has on the LAs themselves (Otero *et al.*, 2010; Otero, 2015; Close *et al.*, 2016; Gray *et al.*, 2016; Top *et al.*, 2018). Students who act as LAs develop stronger scientific identities and are more prone to teaching (Close *et al.*, 2013a, b). Further, LAs who go on to teach middle or high school science, technology, engineering, and mathematics (STEM) courses express greater comfort with using research-supported teaching practices than new teachers who did not act as LAs (Gray and Otero, 2009; Gray *et al.*, 2010).

The incorporation of LAs can also have positive impacts on student learning, improving students' performance on concept inventories (Barrasso and Spilios, 2021) and on higher-order test questions (Sellami *et al.*, 2017). LAs are particularly impactful in larger classrooms where instructors have difficulty facilitating discussion among students (Barrasso and Spilios, 2021). The inclusion of LAs has been linked to lower failure rates and has been found to be especially beneficial to students from underserved groups in both physics and biology courses (Sellami *et al.*, 2017; Van Dusen and Nissen, 2017; Van Dusen and Nissen, 2020; Alzen *et al.*, 2018). The goal of this paper is to build on this body of work to examine how LAs can contribute to more inclusive learning environments for students in introductory biology courses. In the next section, we explore connections between the LA program and models of inclusive teaching.

Connecting the LA Program to Models of Inclusive Teaching Environments

In this work, we draw on Dewsbury and Brame's model of inclusive teaching, which highlights three key elements: 1) a supportive classroom climate, 2) engaging and responsive pedagogical choices, and 3) the integration of campus networks (Dewsbury and Brame, 2019; Dewsbury 2020). A *supportive classroom environment* is one in which students feel welcome, respected, and valued, rather than excluded, unwanted, or isolated (Brame, 2019). It has been found to be an essential precursor to other elements that promote inclusion, such as belonging, development of self-efficacy, and value for course tasks (Connell and Wellborn, 1991; Freeman *et al.*, 2007; Zumbrunn *et al.*, 2014). Importantly, the sense of belonging that is fostered by a supportive, welcoming classroom environment promotes student engagement and subsequent achievement (McKinney *et al.*, 2006; Walton and Cohen, 2011; Graham *et al.*, 2013; Zumbrunn *et al.*, 2014). Another key element in the inclusive teaching model is *engaging and responsive pedagogical choices*. Pedagogies that incorporate active learning, which provides opportunities for students to share their ideas and reasoning in class, are often more engaging for students and provide key information to instructors. In addition, Dewsbury and Brame (2019) point to the need for student feedback to shape instructional choices: "A pedagogical choice can be active, but the degree to which it reflects the instructor-student dialogue is what makes it inclusive" (p. 3). Finally, Dewsbury and Brame highlight the role of *integration of campus networks* for supporting students' inclusion. Rather than keeping classroom spaces isolated from other campus services and opportunities, including those in STEM, this model advocates for incorporating these networks into courses.

In launching the LA program at Vanderbilt, we anticipated that LAs would meaningfully contribute to two elements in this model of inclusive teaching: 1) fostering a more supportive classroom climate and 2) supporting engaging and responsive pedagogical choices. First, LAs may serve as a source of psychosocial support for students (Hernandez *et al.*, 2021). Social support in the classroom can be described as having four components: appraisal support, which includes encouraging feedback and acknowledgment of effort; emotional support, which conveys that the student is accepted and valued; informational support, which includes information and advice about the goals and norms of the class; and instrumental support, which includes information about course content or instructions (Hernandez *et al.*, 2021). Eddy and colleagues (2021) found that LAs in a gateway chemistry course provided appraisal support, emotional support, and informational support, and thereby fostered deep engagement (Hernandez *et al.*, 2021). This finding supports earlier work at the K–12 level indicating that social support increases school identification, value for learning, and engagement in class (Bryson and Hand, 2007; Wang and Eccles, 2012).

In addition to offering these forms of social support to classroom climate, we also anticipated that LAs would impact instructors' pedagogical choices by facilitating the use of active-learning approaches in a course (Barrasso and Spilios, 2021). Given that course instructors meet with LAs in weekly preparation meetings, there are opportunities for LAs to influence instructors' pedagogical choices by sharing feedback from

TABLE 1. Demographic information for courses included in the study[a]

	2019		2020	
	Section with LAs	Section without LAs	Section with LAs	Section without LAs
Number of students	192	181	168	169
Percent female	61%	54%	67%	61%
Percent Asian/Pacific Islander	22%	28%	24%	26%
Percent Black	17%	11%	15%	15%
Percent Hispanic	8%	8%	10%	9%
Percent international	8%	9%	6%	8%
Percent two or more races	6%	6%	5%	6%
Percent white	32%	31%	32%	33%

[a]Categories (defined by the Integrated Postsecondary Education Data System) greater than 5% are reported.

their interactions with students. The LA model therefore offers new ways for responding to students' experiences, even in a large lecture course.

Based on this model of inclusive teaching, we predicted that the incorporation of LAs into a large introductory science course would result in a more supportive classroom environment and more engaging and responsive pedagogical choices, thus increasing students' sense of belonging. We further expected that students would experience a greater sense of engagement in the course, both due to their increased sense of belonging and the LAs' support of active-learning approaches in the classroom. To test these predictions, we sought to answer three questions in this study:

- Does the incorporation of LAs in an introductory biology course increase students' sense of belonging in the course?
- How does the incorporation of LAs impact student engagement and perception of learning in an introductory biology course?
- How does the incorporation of LAs in an introductory biology course impact students' sense of belonging in STEM more broadly?

To answer these questions, we incorporated LAs into one section of a high-enrollment introductory biology course during two semesters, Fall 2019 and Fall 2020. Another section of the course that did not incorporate LAs served as a control during both semesters. Importantly, the course structure differed significantly between 2019 and 2020 due to the COVID-19 pandemic, allowing us to robustly evaluate the impacts of LAs on belonging in two different structures—virtual and in-person—within the same course.

METHODS
Institutional Review Board
This project was determined to be exempt by the Institutional Review Board at Vanderbilt University (IRB ID no. 191 208).

Study Setting and Course Format
LAs were incorporated into one section of BSCI 1510: An Introduction to Biological Sciences in both Fall 2019 and Fall 2020; in each semester, another section of the course that did not incorporate LAs served as a control. Demographic information for each section is provided in Table 1.

Each section of the course is typically taught by two instructors, each taking primary responsibility for half of the semester;

further, each section is taught by a different pair of instructors. Thus, in this study, the instructors in the control and intervention sections were not uniform across years. Specifically, in 2019, the teaching teams were Instructors A and B for the control section and Instructors C and D for the intervention section; in 2020, the teaching teams were Instructors B and E for the control section and Instructors A and C for the LA section.

In Fall 2019, both the experimental and control sections were taught in person, meeting three times per week for 50 minutes. Students were instructed to read textbook material before coming to class. In the section with LAs, class time consisted of lecture interspersed with brief (5–10 minute) active-learning exercises (typically two to three per class session for a total of 10–20 minutes of the 50-minute class period). The LAs were dispersed throughout the lecture hall to maximize students' access to them. LAs facilitated discussion during the active-learning exercises, moving from student group to student group as needed. In the control section without LAs, students were given none to three questions per lecture to discuss with their neighbors. Active-learning exercises occupied 0–10 minutes of the 50-minute class period. In both the control and experimental sections, the instructors tended to stay in the front of the room, beginning and ending active-learning exercises but not specifically facilitating group discussion during the exercises.

Due to the COVID-19 pandemic, in Fall 2020, both the experimental and control sections of BSCI 1510 were taught in a virtual format utilizing a flipped instructional approach. In the experimental section, students were told to watch instructor-recorded videos and to complete an associated worksheet before class. Students received a small amount of credit for completing the worksheet and for attending the Zoom call. Class time consisted of small-group (13–15 student) Zoom sessions in which LAs facilitated discussion of the worksheet throughout the 50-minute session. Unlike 2019, each LA hosted a separate Zoom session and worked with the same group of students throughout the semester. The instructors and a graduate teaching assistant moved between Zoom sessions, ensuring that one instructor visited each Zoom session for at least 10 minutes during each class meeting. The control section was set up similarly using a flipped-classroom approach but did not use a worksheet to organize discussion. A single instructor led a synchronous course discussion over Zoom in which students were encouraged to ask questions about the material for the day. These and other course characteristics are summarized in Table 2.

TABLE 2. Course structures

	Fall 2019		Fall 2020	
	Section with LAs	Section without LAs	Section with LAs	Section without LAs
Ratio of LAs: students	1:~20	N/A	1:~13	N/A
Preclass preparation	Assigned reading	Assigned reading	Assigned reading, videos, and worksheet	Assigned reading and videos
Typical class activities	Lecture interspersed with breakout discussion (2–3 per class; typically 10–20 minutes/class)	Lecture with clicker question-driven discussion (0–3 per class; typically 0–10 minutes/class)	Discussion of worksheet in small groups	Open forum for questions in one large group

In both semesters, the LAs were supported in their work through a pedagogy course taught by faculty members from the Department of Teaching and Learning (H.J.J. and J.W.) as well as weekly meetings with BSCI 1510 instructors in which they previewed and worked through active-learning exercises for the coming week.

Survey Delivery and Analysis

To inform research question 1 (RQ1), the Psychological Sense of School Membership Scale (Goodenow, 1993) as previously modified to measure students' sense of belonging in a single class (Zumbrunn *et al.*, 2014) was delivered to students via the university learning management system, Brightspace. The scale consists of 17 Likert-scale items (see Table 3). An individual Likert score was calculated for each student. This score represented the mean composite of all Likert item responses. Students in sections with and without LAs were asked to complete the survey during the final week of the semester and received a small number of bonus points (<0.5% of total course points) for doing so.

The redundancy of combining Likert-type items to create a Likert scale can justify parametric analysis of the data, that is, treating combined student responses as interval continuous data rather than ordinal (Harwell and Gatti, 2001; Lovelace and Brickman, 2013). To determine whether our data fit the criteria for treatment as interval continuous data, we visualized the data using a Q-Q plot and observed normal distribution. We therefore used parametric methods to analyze the data using GraphPad Prism. Specifically, we used Welch's t test (or an independent t test) to test the mean Likert-scale responses of students in sections with and without LAs for both 2019 and 2020. Each data set was then summarized in a table of descriptive statistics that included mean, standard error of the mean (SEM), SD, and sample size (n). Using the mean and SD, an effect size was calculated using the Cohen's d test. Likert item responses were visualized using a histogram normalized to student response total.

Focus Group Data Collection

To inform research questions 2 and 3 (RQ2 and RQ3), we collected focus group data from students in sections with LAs during the final 2 weeks of class; instructors told students that the data would be collected but were not present during the group discussions. In 2019, 174 out of 192 students (90.6%) were present for the focus group session, while in 2020, 159 out of 168 students (94.6%) were present for the session.

We based our approach to data collection on the small-group analysis method, in which a consultant asks students in their normal classroom setting to form small groups (typically three to four students) to discuss questions and provide written responses; each group provides a single response to the questions, although students are encouraged to indicate if members of the group have different points of view (Clark and Bekey, 1979; Vanderbilt Center for Teaching, 2019). This small-group segment is then followed by a large-group discussion, during which the consultant facilitates a guided group discussion to provide additional elaboration on issues of interest. The consultant collects the written responses, providing access to students' own words as well as the consultant's notes from the larger discussion. Specific modifications are described below.

In 2019, students formed small groups with nearby colleagues and provided handwritten responses on paper. All student responses were collected and transcribed. In 2020, all meetings were conducted via Zoom. Students were therefore put into small groups (i.e., three to four people) with

TABLE 3. Belonging survey derived from the Psychological Sense of School Membership Scale (Goodenow, 1993) as previously modified to measure students' sense of belonging in a single class (Zumbrunn *et al.*, 2014)[a]

Survey item
I feel like a real part of BSCI 1510.
People in this course notice when I'm good at something.
It is hard for people like me to be accepted in this course.*
Other students in this course take my ideas seriously.
The instructors in this course are interested in me.
Sometimes I feel as if I don't belong in this course.*
There's at least one instructor in this course I can talk to if I have a problem.
People in this course are friendly to me.
Instructors in this course are not interested in people like me.
I am included in lots of activities in this course.
I am treated with as much respect as other students.
I feel very different from most other students in this course.*
I can really be myself in this course.
The teachers here respect me.
People in this course know I can do good work.
I wish I were in a different course section.*
Other students in this course like me the way I am.

[a]Students indicated agreement with the students using a five-point Likert scale; an asterisk (*) indicates reverse scoring for the item.

members of their persistent LA group and provided responses via a Google form. Due to technical difficulties, some students were not put in a small group and therefore provided responses as individuals, which they indicated on their forms. In 2020, no large-group discussion was held following the small-group discussion. Therefore, we focused our analysis only on students' written comments for both years. For the question "How has the incorporation of LAs in this course influenced your learning and engagement with the material?," we collected 39 group responses in 2019 and 21 group and 34 individual responses in 2020. For the question "How has the incorporation of LAs in this course influenced your sense of belonging in the STEM field?," we collected 40 group responses in 2019 and 21 group responses and 35 individual responses in 2020. This difference in group size in the two years (i.e., small group only in 2019 vs. a mix of small group and individual in 2020) means that any quantification must be considered as simply an exploratory, question-raising exercise.

Focus Group Analysis

To estimate whether students perceived benefit from incorporation of LAs on their engagement and learning (RQ2) and sense of belonging (RQ3), we categorized student responses as identifying positive, negative, or little/no impact, reporting the percentage of responses in each category. The unit of analysis for these estimates is the entire student response. While this analysis provides some indication of how students perceived LA impacts, it does not identify the means by which students perceived LAs impacted their experience.

To identify means by which LAs impacted students' experience, we used a generative process to interpret student responses to the focus group questions, applying thematic analysis (Guest *et al.*, 2012) to responses to the two questions separately. Specifically, two researchers (C.J.B. and A.J.B.) independently open-coded all responses to each question, identifying themes that emerged. These researchers then discussed the themes, clarifying wording and descriptions for each. These themes then served as a codebook for the remainder of the analysis.

Two researchers (C.J.B. and H.J.J.) then coded and discussed all student responses using this codebook. A given response could have multiple phrases conveying different ideas; the unit of analysis in coding was therefore a phrase connected to one idea. To check and refine the codebook, student responses were coded in at least two rounds. In the first round, these two researchers coded the responses independently. They then discussed the coding of a randomly chosen ~15% responses, resolving discrepancies by consensus (Saldaña, 2015) and refining themes as needed. In the second round, these researchers revisited their coding to apply their refined understanding. They again met to discuss the coding, resolving discrepancies by consensus. During analysis of student responses to the question "How has the incorporation of LAs in this course influenced your sense of belonging in the STEM field?," code saturation was attained by the second meeting, indicating the codes were stable and no new issues were identified; a third meeting was necessary during analysis of student responses to the question "How has the incorporation of LAs in this course influenced your learning and engagement with the material?" Coding was conducted in Microsoft Word and ATLAS.ti.

RESULTS

Research Question 1: Does the Incorporation of LAs in an Introductory Biology Course Increase Students' Sense of Belonging in the Course?

To determine whether the incorporation of LAs had an impact on students' sense of belonging in the class, we used the Psychological Sense of School Membership Scale (Goodenow, 1993) as previously modified to measure students' sense of belonging in a single class (Zumbrunn *et al.*, 2014). The scale consists of 17 items, including items that emphasize student–student interactions (e.g., "Other students in this course like me the way I am") and student–instructor interactions (e.g., "The instructors in this course are interested in me"; see Table 3). Students provide responses indicating degree of agreement using a Likert scale from 1 ("strongly disagree") to 5 ("strongly agree").

We visualized mean Likert score per response using a histogram for both 2019 (Figure 1A) and 2020 (Figure 1C), revealing a rightward (more positive) shift for sections with LAs in both years. Further, the mean Likert scores were higher in sections with LAs in both years: in 2019 the mean score (±SEM) was 3.41 (±0.0496) without LAs and 3.74 (±0.0432) with LAs (Figure 1B); and in 2020, the mean score (±SEM) was 3.52 (±0.0521) without LAs and 3.92 (±0.0473) with LAs (Figure 1D). A Welch's *t* test indicated that the difference between sections with and without LAs was significant ($p < 0.0001$) for both years (Figure 1 and Table 4). We also calculated the effect size of integrating LAs using a Cohen's *d* test, finding a medium to large effect size in both years ($d = 0.570$ in 2019; 0.705 in 2020; Lakens, 2013). This observation indicates students in the sections with LAs reported a sense of belonging that was more than half an SD higher than students in control sections in both years. A summary of the descriptive statistics for each data set can be found in Table 4.

Research Question 2: How Does the Incorporation of LAs Impact Student Engagement and Perception of Learning in an Introductory Biology Course?

To determine how students perceived the impact of LAs, we asked student focus groups, "How has the incorporation of LAs in this course influenced your learning and engagement with the material?" Students generally reported that the incorporation of LAs into the course had a positive influence. In 2019, when LAs worked in an in-person classroom facilitating intermittent discussions, 62% (24 of 39) of focus group responses indicated that the incorporation of LAs had a positive influence on their learning and engagement. In 2020, when LAs facilitated individual Zoom sessions with persistent small groups, 90% of focus group responses (19/21) and 79% of individual responses (27/34) indicated that the presence of LAs had a positive influence on their learning and engagement. The remaining responses provide some clarity about students' concerns, with the majority of these remaining responses indicating that the LAs had little impact (neutral) and some others describing problems.

Student responses revealed four major themes about the impacts of LAs on students' learning and engagement (Figure 2).
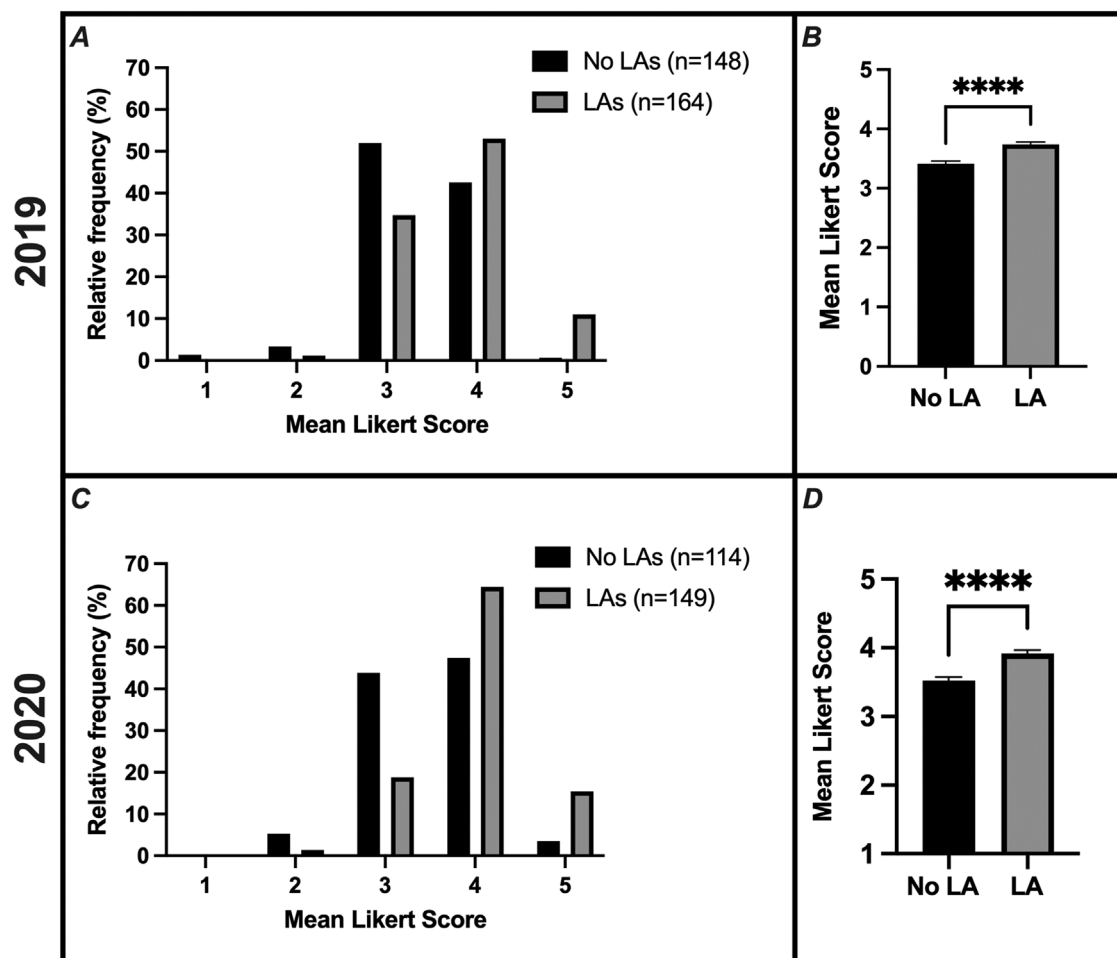
FIGURE 1. Student sense of belonging in course sections with and without LAs. The mean Likert score on the belonging survey is shown for both 2019 and 2020. (A,C) Histograms showing the distribution of student responses. Non-integer means were rounded to nearest integer. (B,D) The mean Likert score per course section was compared using a Welch's *t* test. (****$p < 0.0001$; 2019: no LA = 3.41 [±0.0496], LA = 3.74 [±0.0432]; 2020: no LA = 3.52 [±0.0521], LA = 3.92 [±0.0473])

Theme 1: LAs Were Helpful for Learning and Engagement because of Their Ability to Answer Questions and Provide Clarity. Many student comments highlighted the value of the LAs in helping the students gain a foundational understanding. They noted the usefulness of having a source to explain, to answer questions, and to verify or correct students' understanding during synchronous class sessions:

"Our LA has been very engaging and helpful when it comes to explaining the material and answering any questions related to the material."—group response, 2019

"It was good to have discussions over the worksheets to clarify misconceptions."—group response, 2020

"Our LA helped answer questions during class on lecture topics we were unsure about."—group response, 2020

A subtheme that addressed the supplementary materials or instruction that LAs provided also emerged: LAs facilitated learning and engagement by incorporating additional materials, explanation, or context into lecture materials.

"LAs helped provide personal experiences and helped provide context to the lectures."—group response, 2019

"She also helped pull additional materials to help further our understanding of the material."—group response, 2020

TABLE 4. Descriptive statistics on the mean belonging score of course sections with or without LAs[a]

	No LA			LA					
Year	Mean (±SEM)	SD	*n*	Mean (±SEM)	SD	*n*	ΔMean (±SEM)	*p*	Cohen's *d*
2019	3.41 (±0.0496)	0.603	148	3.74 (±0.0432)	0.554	164	0.326 (±0.0658)	<0.0001	0.570
2020	3.52 (±0.0521)	0.556	114	3.92 (±0.0473)	0.578	149	0.395 (±0.0704)	<0.0001	0.705

[a]Analysis includes a *p* value from a Welch's *t* test comparing mean Likert score within each year and a Cohen's *d* test for effect size.

Research question 2: How does the incorporation of LAs impact student engagement and perception of learning in an introductory biology course?	Research Question 3: How does the incorporation of LAs in an introductory biology course impact students' sense of belonging in STEM more broadly?
Theme 1: LAs were helpful for learning and engagement because of their ability to answer questions and provide clarity.	**Theme 1**: LAs (and the smaller groups they facilitate) decrease feelings of isolation.
Theme 2: LAs were helpful for learning and engagement because they facilitated active and interactive learning.	**Theme 2**: LAs served as inspirational role models for students.
Theme 3: LAs were helpful for learning and engagement because they were accessible, approachable, and provided immediate help.	**Theme 3**: LAs helped students understand how to progress through the STEM educational system.
Theme 4: Not all students found the incorporation of LAs helpful for their engagement and learning.	**Theme 4**: LAs groups helped students become engaged and more confident in their STEM-related knowledge and skills.
	Theme 5: As near peers, LAs were effective sources of support because of their approachability and relatability, especially in comparison with generalized STEM others.

FIGURE 2. Themes that emerged from student responses about the impact of LAs on engagement and learning in the course and belonging in STEM.

Theme 2: LAs Were Helpful for Learning and Engagement because They Facilitated Active and Interactive Learning. Students also noted the value of LAs in making the course more discussion based and interactive. Students noticed this shift away from being a passive learner in a lecture-type format toward being an involved, active participant in class. This shift required them to answer questions, to connect multiple student ideas into a larger conceptual framework, and to be involved in both listening and responding to their peers' contributions to the discussion. In addition to making comments about how their role shifted, students saw the benefits of being more actively engaged in the class sessions to their understanding of the course material.

"They make the class more interactive."—group response, 2019

"Make a STEM class more discussion-based which helped the information stick better than it would through pure memorization."—group response, 2019

Importantly, these responses often highlighted the students' agency, placing their own intellectual work at the center of the changes the LAs made possible:

"Our LA helped us to understand the material more deeply than just the lectures alone. It was more individualized learning, we could ask questions and answer questions for our peers."—group response, 2020

"Most of us liked the way our LA would put us into different breakout rooms. We felt that this encouraged inquiry and made us feel more confident when asking questions."—group response, 2020

"I actively think about ways that I could explain a concept to other students when going over the daily worksheets."—individual response, 2020

"The incorporation of LAs has definitely helped me better grasp the material by discussing the concepts in more detail and applying them to various questions."—individual response, 2020

Some responses also emphasized the value of working with other students, sometimes implicitly by invoking discussion, and sometimes explicitly:

"The LAs positively influenced my learning in my opinion because it was good to be able to discuss the worksheet answers as a group and get insight that I wouldn't have come up with myself."—individual response, 2020

While we observed this theme in responses from both semesters, suggesting that either way of incorporating LAs into a course could promote active and interactive learning, it was more prevalent in 2020, when LAs facilitated individual Zoom sessions with persistent small groups. Specifically, there were approximately four times as many coded phrases corresponding to this theme in 2020 compared with 2019 (39 in 2020 vs.

10 in 2019; 116 total phrases were coded for this question across both years).

Related to this observation, we also noted a subtheme in 2020: students reported that the smaller groups that the LAs facilitated were helpful for engagement, saying that the smaller groups gave them a greater sense of comfort and willingness to engage:

> "I feel like I'm more excited to come to class knowing that I'll be with my small, isolated group of people."—individual response, 2020

> "We appreciated the ability to talk through answers in a more comfortable/less judgmental environment. Having the LAs also let us have smaller groups and more time to speak/ask questions. Also, helped us get a better grasp on what we still needed help understanding."—group response, 2020

Theme 3: LAs Were Helpful for Learning and Engagement because They Were Accessible, Approachable, and Provided Immediate Help. Students also indicated that the incorporation of LAs was particularly helpful, because it increased accessibility of help. Their comments identified several ways this was true: because LAs are peers, they can be less intimidating, and because there are more of them, they are more accessible and can provide "just in time" answers, which helped students perceive better flow in their learning.

> "Efficiency increased, qualified students, answered questions more quickly than writing a prof, less intimidated, increased accessibility."—group response, 2019

> "It makes learning easier and more fun because we can ask questions almost anytime we want and immediately get a response."—group response, 2020

Theme 4: Not All Students Found the Incorporation of LAs Helpful for Their Engagement and Learning. While most responses indicated that the incorporation of LAs helped student perceptions of engagement and learning, some students did not report a positive impact of the LAs (specifically, 19 of 116 of all phrases coded for this question). In some cases, students simply indicated that there was little influence:

> "The LAs didn't have a large impact during class."—group response, 2019

In both implementations of the program, there were a few comments about inexperienced or unprepared LAs who need more knowledge:

> "Oftentimes they were not able to explain the material well enough."—group response, 2019

> " It hasn't negatively affected it but if I had to be completely honest it didn't really have too large of a positive effect either, but that could be due to the fact that the LA wasn't very well prepared."—individual response, 2020

In addition, some comments in both semesters identified course structures—not necessarily related to LAs but linked in the students' view—that were not conducive to maximal learning. In some cases, these comments had to do with timing:

> "The time given to discuss questions can be too long—sometimes feels like wasting class time."—group response, 2019

In 2020, these comments centered on students' dislike of the flipped-classroom approach, in several cases referring to the class Zoom sessions with their LA-facilitated small groups as "mandatory office hours":

> "I personally disliked the incorporation of LAs in this course. While my LA was phenomenal, did his job perfectly, and went above and beyond every single day, I just don't think these sessions really helped. To me, these felt like mandatory office hours. Having more time slots open for office hours would be just as helpful and it wouldn't be as unfair to us since we have to watch an hour of lecture beforehand and then sit in a Zoom call for another hour in mandatory office hours, even if we don't have questions."—individual response, 2020

Importantly, there was one comment in each semester indicating that students perceived interactions with LAs as causing unwelcome stress:

> "They gave us anxiety when they approached us with questions."—group response, 2019

> "Discouraging in a way to be called out if I don't understand or don't have all of the work completed."—individual response, 2020

Thus, the themes that emerged from students' responses about their engagement and learning highlight benefits of incorporating LAs that can be emphasized and further bolstered as well as potential drawbacks that instructors may mitigate through attention to LA selection and support, course structures, or instructor talk (Seidel *et al.*, 2015).

Research Question 3: How Does the Incorporation of LAs in an Introductory Biology Course Impact Students' Sense of Belonging in STEM More Broadly?

To determine how students perceived the impact of LAs on their belonging in STEM, we asked student focus groups, "How has the incorporation of LAs in this course influenced your sense of belonging in the STEM field?" Students generally reported that the incorporation of LAs into the course had a positive impact on their sense of belonging in STEM: 60% (24 of 40) of responses (all from groups) in 2019 and 67% (14/21) of group responses and 63% of individual responses (22/35) in 2020 indicated that LAs increased student sense of belonging. Other than a single response—which indicated that time with the professor was more limited because of the LAs—the remaining responses indicated that LAs neither helped nor hurt students' sense of belonging. Thus, while these data are not conducive to statistical analysis, more than half of student responses indicated a positive impact, and almost none indicated a negative impact.

Importantly, the responses revealed some of the ways in which having LAs and the small-group work they fostered promote belonging (Figure 2).

Theme 1: LAs (and the Smaller Groups They Facilitate) Decrease Feelings of Isolation. Students noted that the incorporation of LAs into the course gave them the opportunity to form connections and a greater sense of community. They described feeling more included, often due to a decreased sense of being alone. Some of the responses explicitly address the larger STEM community, while others focus on decreased isolation in this particular STEM course.

"Smaller groups made people more comfortable expressing what they didn't understand which in turn made all the students feel more comfortable with the concept of not understanding things. In a sense, it allowed people to see that they weren't the only person with questions and feel more incorporated in the STEM community."—group response, 2020

"Yes, I felt much more welcome in my group rather than the isolated feeling that often accompanies larger lectures."—individual response, 2020

"It made me feel like a bigger part of the STEM community by talking and learning with the LAs."—group response, 2019

"1) Due to having a lot of female LAs, I feel more included. The overall diversity makes everyone feel included 2) Similar struggles can be shared with LAs and makes us feel less 'alone.'"—group response, 2019

In several instances, students noted that seeing LAs with whom they shared identities helped them feel more included and welcomed.

"The LA groups allowed us to get to know other people as students and see that 'I' am not the only student struggling. It also allowed us to see other Black students, and with STEM having a Black-minority, it brought forth some sense of comfort in the fact."—individual response, 2020

"Having a female LA and being in a group with almost all women made me feel even more included."—individual response, 2020

Theme 2: LAs Served as Inspirational Role Models for Students. Another theme that emerged from student comments was that LAs could serve as examples of near peers who could inspire them, increasing their confidence in their own ability to succeed.

"Nice to talk to the LAs who are experiencing the same rigor with courses, seeing role models and students that are in a place we want to be in."—group response, 2020

"LA[s] can be a boost of confidence as they are someone our age who have gotten through the intro level courses."—group response, 2020

"Seeing people who went through it and know the material by understanding the process makes doing well seem possible ↑ [up arrow] belonging in STEM field."—group response, 2019

Here, too, students noted the importance of LAs with whom they shared identities. While seeing LAs with shared identities could reduce students' sense of being alone and isolated, as indicated in theme 1, some student comments also indicated that it could be inspirational, encouraging students to stick with a desired path.

"Seeing black, female LAs was super encouraging!"—group response, 2019

"My LA inspires me as I see a woman of color being a leader in the STEM field, and I hope to achieve similar things as she has."—individual response, 2020

Theme 3: LAs Helped Students Understand How to Progress through the STEM Educational System. One relatively unexpected theme that emerged involved LAs' ability to demystify the path through the STEM educational system, both at our institution and within STEM more broadly. Students offered comments about LAs' help with understanding how to successfully navigate their undergraduate careers, from choosing classes to identifying research opportunities and interesting clubs. They also commented on LAs' advice on preparing for graduate school, medical school, or future career opportunities.

"Presents a mentor for the STEM field (what the STEM path is like, how to obtain opportunities in STEM, courses/professors to take)."—group response, 2020

"Because our LA is applying to MD/PhD programs we were able to ask him questions about that and see what kinds of students were involved in specifically premed society."—group response, 2020

"The incorporation of LAs provided insight into the specificities of the STEM field in terms of encouragement and participation in research opportunities on campus."—group response, 2019

"They helped encourage us and introduce us to other aspects of the STEM field."—group response, 2019

Theme 4: LA Groups Helped Students Become Engaged and More Confident in Their STEM-Related Knowledge and Skills. One of the ways that students indicated that incorporation of LAs increased their sense of belonging was through an increase in their engagement with and confidence about STEM-related knowledge and skills, emphasizing the relationship between their engagement and learning (RQ2) and their sense of belonging in STEM (RQ3). In some instances, students noted that the LAs and the small groups they made possible helped with a sense of understanding; in other cases, they emphasized their increased ability to ask questions, echoing the sense of agency promoted by LA groups that we saw earlier.

"Sense of belonging is higher because we are more involved and engaged, she answered a lot of questions that we would not have answered in a lecture setting so we understand the material better."—group response, 2020

"It was easier to ask questions in this setting, and the LA setup helped us understand biology better."—group response, 2020

"Our LA has made us feel a lot more positive and confident to be in the STEM field. It is a daunting class but the LAs make us feel more engaged."—group response, 2019

"I feel better able to take part in intellectual conversations and offer more impactful discussion."—individual response, 2020

While these data do not allow for robust quantitative analysis, it is worth noting that this theme was more prevalent in student comments from 2020, when LAs facilitated discussion in persistent groups via Zoom, than in 2019, when LAs facilitated intermittent classroom discussion (i.e., 13 vs. three phrases corresponding to this theme out of a total of 86 coded phrases for this question).

Theme 5: As Near Peers, LAs Were Effective Sources of Support because of Their Approachability and Relatability, Especially in Comparison with Generalized STEM Others. Echoing a theme from student responses about how LAs impacted their engagement and learning, students noted that LAs' status as near peers made them helpful sources of support.

"Sometimes big lectures with incredible, knowledgeable professors can be pretty intimidating and make a career in the STEM field seem competitive/far-fetched, so having undergrads who are really friendly + personable is really encouraging."—group response, 2019

"It was nice to have someone who was a current student and was able to relate personally to what we are going through and has recently learned the material as well."—group response, 2020

"More personalized. Undergrad students, so they feel more relatable and friendly."—group response, 2020

DISCUSSION

In this study, we present evidence that LAs in an introductory biology course supported students' sense of belonging and engagement. These findings were consistent across two very different structures (in-person in 2019, virtual in 2020) for incorporating LAs into the course, showing that an LA program can be a robust mechanism for creating more inclusive and supportive learning environments in an introductory STEM course. In this *Discussion*, we connect back to the three key elements in our model of inclusive teaching (Dewsbury and Brame, 2019; Dewsbury, 2020) and discuss how our findings shed light on ways an LA program can foster inclusion in introductory course.

First, we predicted that the LAs would play a key role in nurturing *a supportive classroom climate*, a key element in inclusive teaching. Both our survey findings and the focus group responses indicated that the incorporation of LAs increased student sense of belonging, an important indicator of a supportive climate. Further, focus group responses provided evidence that LAs offered social support, specifically emotional support, informational support, and instrumental support to introductory biology students. Emotional support was an important factor in both

years, as evidenced by themes that emerged in student responses about belonging: LAs and the smaller groups they facilitated decreased feelings of isolation, aided by LAs' approachability and relatability (see Figure 2). Students also pointed to instrumental support (aid, material resources, or needed services; LAs clarifying task instructions and answering questions or helping with points of confusion with the content), as evidenced by one theme that emerged from student responses about engagement and learning: LAs were helpful for learning and engagement because of their ability to answer questions and provide clarity. Students also valued informational support from LAs (information and advice; helping students identify goals and norms of the class, emphasizing that putting effort into learning can lead to improvement, the class is focused on understanding not performance, and learning requires being active).

Additionally, we see evidence that LAs supported another key element in the model of inclusive teaching: *engaging and responsive pedagogical choices*. Several themes that emerged from student responses are related to this element, notably that LAs helped learning and engagement because they facilitated active and interactive learning and because they were accessible and could provide immediate help. In both years, course instructors met with LAs in weekly preparation sessions, making adaptions to their teaching in response to LA feedback. Incorporating LAs allowed for more active-learning pedagogies, with small-group discussions on conceptual questions. We suggest that these responsive pedagogical choices were critical to the theme that emerged showing that students with LAs reported being more engaged and confident in their learning, a finding that echoed earlier work from Schick (2018). Notably, this theme was more prevalent in 2020 than 2019, perhaps not surprising given the large structural differences in the courses and how the LAs were deployed. In 2019, the LAs facilitated small-group activities interspersed in lecture, floating among groups that could shift over the course of the semester. In 2020, each LA facilitated discussions based on a worksheet throughout each class session within a consistent small group via Zoom. With smaller groups and greater agency over their small-group structures, LAs were able to be more responsive to student needs, interests, and strengths. Therefore, the structure of the LA work in 2020 allowed for more discussion time during the sessions, consistent groups to build relationships, and more responsive pedagogical choices. As a consequence, LAs could also provide more nuanced and detailed feedback to instructors, allowing adaptations to the larger course as it proceeded. We hypothesize that these factors all contributed to the greater impact of LAs on student engagement and perception of learning in 2020 and that these factors help students feel as if they belong in the STEM community. This finding is especially exciting given that the class was taught virtually, with some students not even physically on campus or in the same time zone. Despite these challenges, this small-group approach helped students feel like part of the university as a whole and make connections with their peers.

The final element in the model of inclusive teaching was *leveraging campus networks*. While we did not predict that LAs would contribute meaningfully to this element, a theme emerged from student responses about belonging that suggested that LAs did contribute: LAs helped students understand how to progress through the STEM educational system. Thus,

our findings suggest that LAs helped students gain access to campus networks, particularly in STEM areas. Students reported greater access to and knowledge about STEM organizations, such as the pre-med society, and increased awareness of research opportunities and other aspects of the educational system. These observations, which correspond to those previously reported in physics, suggest that helping LAs conceive of their role more broadly in supporting students' navigation of the STEM educational systems at their institutions will further foster inclusivity in introductory courses (Goertzen *et al.*, 2013).

In addition to showing how the LA program supports more inclusive teaching in introductory biology, our findings hold implications for the design and structure of LA programs. Focus group responses point to the need for recruiting LAs with diverse backgrounds, particularly those with marginalized racial, ethnic, and gender identities. Given the limited diversity of professors in STEM fields, placing more minoritized students in these leadership roles is a (small) step toward addressing problems of representation. Based on our experiences as LA course and pedagogy course instructors, we have also observed anecdotally that some LAs bring political clarity (Beauboeuf-Lafontant, 1999; Madkins and McKinney de Royston, 2019) to their roles, seeking to support younger students and mitigate the racialized, classed, and gendered harm that STEM environments often inflict. While it should not be up to minoritized students to carry the burden of creating more inclusive STEM environments, LA programs should allow for and learn from their creativity and agency in these roles. For instance, the LA pedagogy course should explicitly address issues of equity and inclusion (and not just for a couple weeks at the end of the semester) and offer tailored support for minoritized LAs to address the specific opportunities and challenges they might experience in this role (White, 2020).

Finally, it is relevant to mention that the addition of LAs requires investment by the instructor in the development of active-learning approaches in the course with significant time required to design and implement these types of activities. Furthermore, instructors must remain dedicated to the preparation and support of LAs throughout the semester. Based on the nine themes we have observed and their demonstrated impact on student belonging, this additional effort is well spent.

Limitations
To examine the impact of LAs on students' sense of belonging in an introductory biology course, we compared students' survey responses in one section of the course with LAs and one without LAs over the course of two semesters. While the incorporation of LAs was not advertised before or during registration and could not have been a factor in students' section choice during these two semesters, students were not randomly assigned to the conditions but instead chose a section based on course time, instructor, or other factors. (It is worth noting that one instructor, K.L.F., taught in the control section in 2019 and in the experimental section in 2020, while another instructor taught in the experimental section in 2019 and the control in 2020.) This may have resulted in a nonrandom distribution that impacted our results. In addition, instructor styles vary, and this variation could influence LAs' interactions with and subsequent impact on students in the course. Further studies should investigate how variation in instructor talk, worksheet/question structure, and other course design elements influence the effects that LAs have on student experiences.

We did not collect demographic data as part of the survey and are therefore unable to disaggregate student responses. While focus group responses support our claim that incorporation of LAs made this introductory biology course more inclusive, further studies should specifically investigate the impact of LAs on minoritized groups.

To determine the ways in which students perceived that LAs impacted their experiences in the course, we asked student focus groups to provide written responses to questions about engagement and learning and about belonging. While we encouraged students to record all ideas that emerged in their groups and did see evidence of difference experiences in a single group response, some students may have felt uncomfortable sharing their points of view in this setting. Further, during the semester in which the course was virtual, some students responded to these questions in small groups while others responded to them individually due to technical problems with moving students into groups. This difference in group size means that some students may be overrepresented in our focus group responses. It is also important to note that the phrasing of the focus group questions ("How has the incorporation of LAs in this course influenced your learning and engagement with the material?," "How has the incorporation of LAs in this course influenced your sense of belonging in the STEM field?") may have unintentionally introduced a bias toward positive responses. While some student responses indicated that the incorporation of LAs had little impact, different question phrasing may have resulted in more of these responses.

CONCLUSION
In this study, we examined the impact of an LA program on students' sense of belonging as a key indicator of an inclusive learning environment in an introductory biology course. We found that incorporation of LAs increased students' sense of belonging in the course in two semesters when the course was taught using very different structures, exhibiting a medium to large effect size in both semesters. Further, student focus groups revealed some of the ways in which LAs impacted their experience. Specifically, we found that LAs promoted learning and engagement by answering questions and providing clarity; allowed more use of active- and interactive-learning structures; and served as accessible, approachable, and immediate sources of help. Further, students said that LAs promoted a sense of belonging in STEM by decreasing feelings of isolation, serving as inspirational role models, clarifying progression through the STEM educational system, and helping students become more engaged and confident in their STEM-related knowledge and skills. These findings indicate that LAs contribute to three elements of inclusive STEM teaching: a supportive classroom environment, engaging and responsive pedagogical choices, and, somewhat surprisingly, integration of campus networks. Further, these findings provide guidance for effective selection, support, and mentoring of LAs to help maximize their impact.

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