Insights into Student Perceptions of Learning Assistants in Calculus I: A Mixed-Methods Study Involving Survey and NLP Analysis

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Increasingly, institutions of higher education utilize undergraduate Learning Assistants (LAs) to support students' learning in introductory calculus courses. Prior research has shown a promising impact of the LAs on students' success and retention. However, little is known about students' perceptions of LAs' roles or whether academic factors influence these perceptions. In this mixed-methods study, we analyzed 411 Calculus I students' survey responses. The results of statistical analysis indicate that, regardless of course performance or prior Calculus experience, students generally perceive LAs positively, with students who seek additional learning resources having even more favorable perceptions of LAs. Additionally, a natural language processing (NLP) technique– topic modeling—revealed two themes: Investigating Procedural Activities and Conceptually Framing Results through Collaboration. Findings support LAs' role in fostering meaningful engagement for a range of students and demonstrate the value of NLP in educational research, offering insights for LA support of active learning in Calculus courses.

Keywords: Learning Assistants, Calculus, Student Perceptions

Improving students' learning experiences in university Calculus courses has been at the forefront of many reform efforts by higher education institutions (Bressoud, 2020; Rasmussen et al., 2014). Some reform approaches involve studio course designs, group problem-solving, and personal response systems, all of which emphasize active learning. Active learning is broadly conceptualized as encompassing pedagogical approaches that center student contributions and are often viewed as the antithesis of lecturing (Freeman et al., 2014). The *Learning Assistant (LA) model* is one approach to implementing active learning that has been shown to support students' learning, engagement, and retention in the introductory STEM courses (Barrasso & Spilios, 2021). LAs are undergraduate near-peer tutors who have previously completed the course they LA for and receive pedagogical training. LAs are present in the classroom alongside an instructor and support students' learning and interactions in small groups (Otero et al., 2010).

While it has been shown that students in LA-supported courses have better content-related and affective outcomes than their peers without such support (e.g., Alzen et al., 2018), little is known about how students perceive the role of their LA within the classroom. Understanding students' perceptions of LAs' classroom roles can enhance our understanding of how to support student success in STEM courses, since students' perceptions of the course are closely linked to their persistence in STEM (Ellis et al., 2014). Recent studies have examined variation in LA-student interactions (e.g., Carlos et al., 2023) and LAs' reflections on these interactions (Butler & Buchbinder, 2023). However, students' perspectives of these interactions remain largely unexplored, including whether certain groups of students find LAs particularly helpful or not, in other words, "who benefits from interactions with LAs." Our study aims to address this gap.

Specifically, we investigate whether there are differences among Calculus students' perceptions of their interactions with LAs with respect to such variables as: final course grade, previous Calculus experience, and students' pursuit of extracurricular resources. We approach this topic through a mixed-methods analysis of Calculus I students' end-of-course survey responses about their classroom interactions with LAs. Our research questions are:

1. Do students' perceptions of their LAs differ based upon their final course grades, previous calculus experience, or utilization of resources outside of the classroom?
2. How do students describe their classroom interactions with LAs?

Prior to addressing our research questions, we conducted a psychometric analysis of the survey instrument to evaluate its validity, reliability, and overall measurement quality.

Theoretical Framing

We frame LA-student interactions within a Vygotskian sociocultural perspective on learning (Vygotsky, 1978). This perspective holds that substantial learning occurs through social interactions of individuals with a more knowledgeable other (MKO). We conceptualize LAs as MKOs since they have previously taken Calculus I at the institution of study and are tasked with aiding student learning through social engagement. This lends theoretical legitimacy to the notion that students' perspectives on their LAs' classroom roles may be distinct from how they perceive other university instructors due to differences in social and power dynamics involved.

To guide the design of survey items (described in the methods section), we utilized positioning theory and social support theory. Positioning theory attends to the ways in which individuals take up or reject broader social roles by describing the "types of rights and duties people draw on as they interact" (Herbel-Eisenmann et al., 2016, p. 103). Survey items were formulated with the aim of understanding how students perceive the "rights and duties" of their LAs within the context of a Calculus I classroom. Social support theory was utilized to further specify the specific "rights and duties" represented in these items. Social support is a well-established framework from psychology that describes one's perception that they are cared for by others (Taylor, 2011). Within the context of mathematics education, previous research has shown positive connections between levels of social support and learning-related constructs such as ability perception, self-efficacy, and grades across a variety of contexts (Monteiro, 2017).

Social support theory has been previously utilized to investigate students' perceptions of their interactions with LAs (e.g., Donis et al., 2024; Hernandez et al., 2021). These studies identified the types of social support that students perceive from LAs (emotional, informational, appraisal), and that this social support is positively related to student engagement.

Topic Modeling

To analyze open-ended students' responses, we used *topic modeling*, a natural language processing (NLP) method that utilizes unsupervised machine learning and statistical methods to categorize large corpora of text data, like open-ended survey responses (Finch et al., 2018). We utilize the Latent Dirichlet Allocation (LDA) approach to topic modeling, which generates collections of words, called topics, that frequently appear together (Chauhan & Shah, 2021). Each word within a topic has an associated probability indicating how strongly it is associated with a particular topic. From these probabilities, the proportion of each topic within each open response is determined. Thus, a single response may contain a mixture of topics, reflecting the complexity of natural language (Silge & Robinson, 2017). While the association of words with a topic is determined quantitatively by NLP, the themes underlying each topic are determined by the researcher qualitatively, considering the nature of the data (Hwang et al., 2023).

Topic modeling is a novel technique that has recently been applied in mathematics education research (Gökdağ & Özmantar, 2024; Copur-Gencturk et al., 2023). We illustrate how this novel technique can be used to analyze Calculus student survey responses.

Methods

Setting and Data Collection

This study was conducted at a large, public university in the northeastern United States. It is one component of a larger NSF-funded project that aims to transform introductory STEM courses in biology, chemistry, mathematics, and physics through active learning pedagogies. Within the mathematics department, these transformations began with the Calculus I recitations. Calculus I course follows a lecture-recitation format, where students attend a large lecture (~ 150 students) three times weekly and a smaller recitation section (~ 20 students) twice weekly. In the lecture, a faculty member presents information via traditional lecture methods. Recitations are facilitated by a graduate teaching assistant (GTA) and an undergraduate LA who jointly facilitate students' problem-solving activities in small groups. GTAs have a more authoritative role, as they are responsible for assigning groups, grading quizzes, and reviewing content.

To capture students' perceptions of the course, the research team developed a student survey and piloted it for two semesters. The items were adapted from the SEMINAL project's Student Postsecondary Instructional Practices Survey for Mathematics (Uhing et al., 2020). The survey comprises 35 Likert-scale items, scored on a 5-point scale, and six open-response items. Of those, ten Likert items and one open-response item specifically focused on students' perceptions of LAs' roles in recitations (Figure 1). Items 1-4 and 8 were sourced from Hernandez et al (2021); others were developed by the research team to capture nuances of LA-student interaction in Calculus recitations.

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
1. My LA understands the challenges students face in this course.	○	○	○	○	○
2. My LA shares additional resources that help me be successful in this class.	○	○	○	○	○
3. My LA gives me helpful feedback on my work in recitation.	○	○	○	○	○
4. My LA encourages me to keep trying even when I am struggling.	○	○	○	○	○
5. My LA explains problems in ways that make sense to me.	○	○	○	○	○
6. My LA explains mathematical concepts in ways that I can easily understand.	○	○	○	○	○
7. My LA asks me questions more often than they tell me answers.	○	○	○	○	○
8. My LA helps me understand recitation activity instructions.	○	○	○	○	○
9. I ask my LA for advice about courses other than calculus.	○	○	○	○	○
10. I feel comfortable sharing my thoughts with my LA, even when I think I might be wrong.	○	○	○	○	○

How would you describe a typical interaction between you (your group) and the LA during recitations? Be as specific as possible.

Figure 1. LA-related Survey Items

The survey was administered during a recitation in the last two weeks of the course by researchers while the GTA and LA were out of the room. Data were collected for three semesters, across 37 different recitation sections staffed by 10 different GTAs and 7 different LAs. Of the 606 students enrolled in the course during these three semesters, 411 consented to have their responses analyzed (~68% response rate). The authors of this paper were researchers on the project and had no teaching or administrative roles in the courses studied.

Instrument Validity and Reliability

To determine the validity of these ten items as measuring the single construct of students' perceptions of LAs' classroom roles, we used exploratory factor analysis (EFA). EFA is a multivariate statistical method that identifies latent variables in a set of directly measured variables (Finch, 2020). To ensure that this data set was suitable for the application of EFA, we conducted Bartlett's Test of Sphericity (showed significance at $p<0.001$) and the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (returned values for each item above 0.89), indicating suitability of EFA (Shrestha, 2021). The EFA revealed that the instrument measures a single latent variable, with item loading factors ranging from 0.5 to 0.9, indicating moderate to strong loading (Batterton & Hale, 2017). The survey reliability was acceptable across measures, with Cronbach's alpha (0.90), split-half reliability (0.82), and McDonald's omega (0.94) all exceeding the recommended 0.7 threshold (Streiner & Norman, 2008). All psychometric analyses were conducted using the R packages *psych* and *GPArotation* (Revelle, 2017).

Analytic Procedures

A non-parametric approach was selected for this study due to the ordinal nature of the data and non-normal distribution of responses (see Table 1 in the Results section). A Bonferroni correction was applied to the Mann-Whitney p-value because multiple tests were run on the data, and to reduce the risk of Type I error (Armstrong, 2014). In the case of a significant difference ($p < 0.1$), Cliff's Delta was computed as a post-hoc test to determine effect sizes (Meissel & Yao, 2024). These statistics were computed using the R package rstatix (Kassambara, 2019).

Since some students in the sample had the same LA, both within and across the semesters, the sample could be considered as LA-dependent. However, after aggregating the data by LA, the mean difference between LAs across all ten items was 0.61, which is relatively minor for our Likert scale. This suggests that students' overall perceptions did not differ dramatically across LAs and that the sample can be considered holistically.

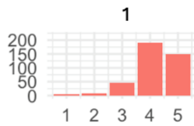
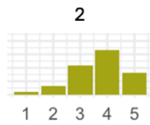
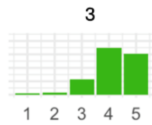
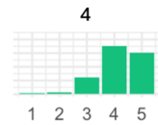
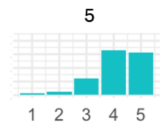
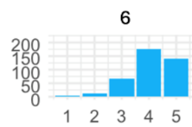
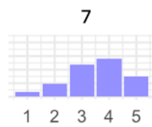
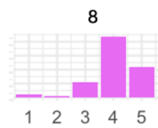
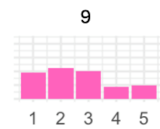
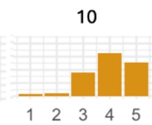
To perform topic modeling on the open-response item, we first conducted pre-processing, or text cleaning (Hvitfeldt & Silge, 2021). First, we removed stop words, which are parts of speech that typically carry little substantive meaning (e.g., a, the, did, or), using three R packages: *SpacyR*, *tidytext*, and *dplyr*. Next, we used the *SnowballC* package to reduce the remaining words to their root forms (Welbers et al., 2017), i.e., the words "explains", "explained", "explaining" are all reduced to their common stem, "explain." After text cleaning, we used the R package *ldatuning* to find the optimal number of topics in our dataset by selecting the number of topics that minimized the CaoJuan2009 metric (Nikita & Chaney, 2022). This resulted in two topics. We then used the R package *topicmodels* to construct the topic model with two topics and an alpha hyperparameter of 0.1 (Grün & Hornik, 2011). This low alpha indicates that topics are sparsely distributed across responses, aligning with our aim to capture features of LA-student interactions at the individual response level (Du, 2022).

Results

Likert Scale Item Analysis

For ease of communication, we refer to the set of 10 LA-related items in Figure 1 as the LA survey. Table 1 shows descriptive statistics for all items in the LA survey, indicating that students generally agreed with most survey items. This suggests that students' views of LAs' classroom roles were positively oriented. The exception to this trend is item 9, with a mean of 2.59 and a mode of 2, indicating relative disagreement with the statement: "I ask my LA for advice about courses other than calculus." Although this role was not explicitly required of LAs, the item was included in the survey to gauge whether LAs act as peer-mentors beyond the calculus course. Some students reported engaging with LAs in this way; most students did not.

Table 1. Descriptive Statistics of Student Responses to LA-Related Likert Scale Items

Item					
Mean	4.18	3.69	4.16	4.15	4.14
Standard Deviation	0.82	0.98	0.84	0.84	0.88
Median	4	4	4	4	4
Item					
Mean	4.09	3.52	4.04	2.59	3.98
Standard Deviation	0.86	1.07	0.83	1.29	0.90
Median	4	4	4	2	4

To explore whether students' perceptions of LAs differ by their final course grades, student responses to the LA survey were split into two groups: 238 high performers—students whose final course grade was B- or better, and 173 general/low performers—the remaining students. Mann-Whitney tests with a Bonferroni correction were conducted to determine whether these two groups responded differently to each of the ten survey items. No significant differences at the p=0.1 level were found, meaning that our data did not provide evidence that students' perceptions of their LAs varied by course performance.

To determine whether perceptions of LAs varied by previous experience with Calculus, student responses were divided into two groups: 174 students who self-reported having previous calculus experience and 237 students without such experience. Again, Mann-Whitney tests with a Bonferroni correction showed no significant differences between the groups at the p=0.1 level.

Next, we divided student responses into two groups based on their self-reported use of learning resources outside the course, such as the university mathematics tutoring center, online videos and other sources. There were 315 students who reported using such resources versus 91 students who did not. Mann-Whitney tests with a Bonferroni correction identified significant differences between these two groups only for items 2, 3, 4, 7, and 10 (Table 2). Since significant differences were found for these items, Cliff's Delta was computed post-hoc to determine the effect size. The results suggest that students who tend to seek outside help have more positive perceptions of LAs' roles, captured by these five items, compared to students who do not seek outside help. However, the effect sizes for all items are small (Meisel & Yao, 2024).

Table 2. Statistics for Students Who do and do not Utilize Outside Resources

Item Number	Mean Response from Students Seeking Help	Mean Response from Students not Seeking Help	Adjusted *p-value*	Cliff's Delta
2	3.77	3.42	0.00417*	0.231
3	4.21	3.97	0.0230*	0.195
4	4.2	3.96	0.0235*	0.195
7	3.61	3.22	0.00746*	0.224
10	3.82	4.03	0.0897**	0.171

Topic Modeling

Topic modeling of student responses to the open-ended question "How would you describe a typical interaction between you (your group) and the LA during recitations? Be as specific as possible" revealed two topics. Figure 2 shows the 20 words most strongly associated with each topic. For clarity, the words are displayed in full, rather than stemmed (e.g., solve instead of solv, easy instead of easi). The horizontal axis shows the probability of the word appearing within the topic; higher values indicate that a word is more strongly associated with a topic.

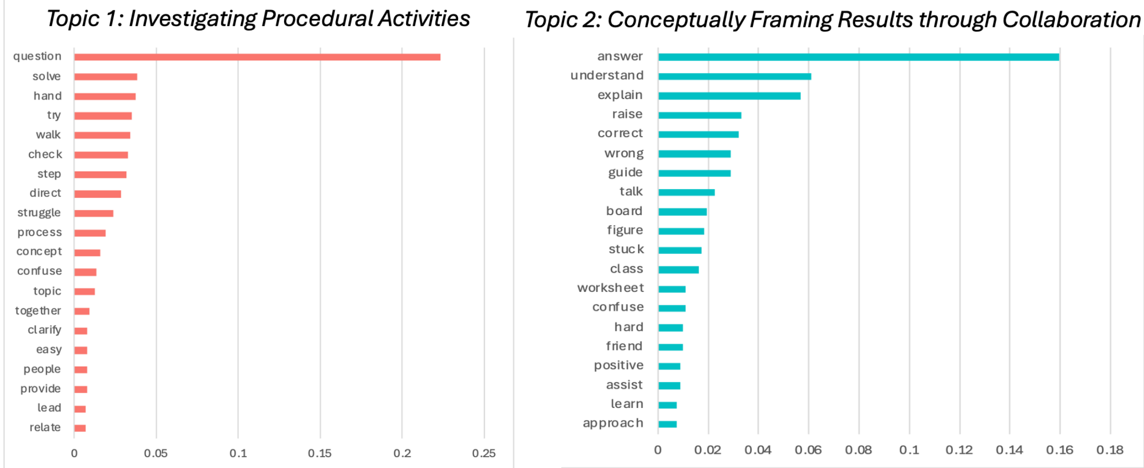


Figure 2. 20 Most Common Words in Each Topic

The first topic (Figure 2, left) includes words like *solve*, *step*, *process*, reflecting a focus on procedural aspects of Calculus. The word most strongly associated with this topic is *question*. Although it is unclear who is asking these questions (i.e., the LA or the student) or if it refers to questions on the worksheet, this word may indicate some procedural focus. The presence of words like *check*, *direct*, *provide*, *clarify*, and *lead* point to the utilization of the LAs' expertise to validate these procedural foci. The presence of the words *try* and *struggle* in this topic suggests some aspects of student difficulty or effort involved in these procedures. For example, in one response that is strongly associated with this topic, the student described "asking [LAs] specific questions when struggling or ask to have work looked over for errors and constructive criticism." Overall, the terms in this topic signal an engagement with the completion of mathematical procedures; thus, the topic was termed *Investigating Procedural Activities.*

The second topic (Figure 2, right) contains terms such as understand, explain, learn, approach, and figure (in the sense of a graph or a sketch), indicating a more conceptual focus within the topic, in contrast to the procedural focus of the previous topic. This topic also contains the terms answer, correct, and wrong, meaning that conceptual discussions were still centered on the correctness of mathematical outputs. This topic also contains words with a strong community orientation, such as guide, talk, board, class, friend, and assist, suggesting collaborative efforts during LA-student interactions. A sample response strongly associated with this topic is: "we work on a worksheet with groups and then we call [the LA] over if we are stuck and she guides us towards the right answer." We termed this topic Conceptually Framing Results through Collaboration since the frequent terms appear to represent outcome-oriented discussions between LAs and students.

Due to the nature of topic modeling, these topics are not necessarily mutually exclusive, meaning that students could describe their interactions with LAs as related to both topics. Our analysis reveals that there are two primary ways in which our students view their interactions with LAs. Some aspects of interactions focus on dissecting specific procedural steps, while others are centered on communal engagement and understanding of outcomes.

Discussion

Statistical analysis of the LA survey revealed that across three semesters of data, *students had relatively positive perceptions of their interactions with LAs*, regardless of the LA. Also, there were no statistically significant differences between groups with high and general/low course performance, nor between groups of students with or without prior calculus experience. We consider this lack of statistical significance as *a positive result,* as it suggests that *all students viewed LAs' classroom presence as beneficial to them*: the struggling students, and the ones with a mastery of the material, those who encountered calculus for the first time and those with prior exposure to it. Statistically significant differences were only found for five Likert-scale items between students who do and do not report utilizing outside resources to aid their coursework. *Students who reported using such resources indicated slightly more positive perceptions of LAs' classroom roles*. This could be because students who seek additional learning resources tend to view LA as one such resource and were more comfortable with or proactive in obtaining LAs' assistance with their mathematical work.

The topic model indicated two primary ways in which students framed their interactions with LAs, which we termed *Investigating Procedural Activities* and *Conceptually Framing Results through Collaboration*. These two topics could provide insight into the reasons behind the often-reported student success in LA-supported courses (e.g., Alzen et al., 2018), specifically that LAs engage with both *students' procedural questions and conceptual discussion of mathematical results.* However, additional work is required to establish this connection.

Our findings align with the studies showing students' satisfaction with their interactions with LAs in large-lecture STEM classrooms (Donis et al., 2024; Hernandez et al., 2021). We extend this literature to the context of Calculus recitation sections led by GTAs. Since the instructional and power dynamics of this environment differ from those of a large lecture, establishing positive student experiences in this context is an important result. The results of this study are also relevant to the broader context of calculus reform, offering support for the LA model's impact as a transformation effort. Our results suggest that these efforts can reach students from a range of different mathematical backgrounds and achievement levels. Although focused on LAs, these findings also inform GTAs, especially those without prior pedagogical experience, by illustrating effective instructional practices. The identified themes—*Investigating Procedural Activities* and *Conceptually Framing Results through Collaboration*—offer concrete examples of valuable classroom support that can be highlighted in both LA and GTA training.

We also offer a *methodological contribution, illustrating the power of NLP tools in analyzing open-ended survey responses.* The use of topic modeling allowed us to broadly describe trends across a large volume of open-ended responses without manual open coding, but with the input and supervision of a researcher. As the use of NLP in education research continues to grow, developing best practices for the validation and interpretation of these automated analyses will be crucial to ensuring their appropriate use in understanding student experiences.

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