Measuring and analyzing teaching assistant comfort with content in a reformed introductory physics laboratory course

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Across the United States, Introductory Physics Labs are typically broken into multiple sections taught by (often graduate) Teaching Assistants (TAs). At CU Denver, the reformed Introductory Physics Lab TAs are mostly undergraduate physics majors. As part of a larger project studying the transformation and efficacy of these labs, we seek to understand how our TAs prepare, and specifically their comfort with the material. We have designed weekly surveys for our TAs and implemented them over multiple semesters. These surveys probe changes to TA comfort throughout the week: specifically before the preparatory meetings, after the meetings but before teaching, and after teaching. We present a preliminary analysis of these data over one academic year. Results indicate that self-reported TA comfort with the material was high before the weekly meeting and increased or stayed constant afterwards. Changes in comfort following teaching are also discussed, with more mixed results.

2025 PERC Proceedings edited by Pawl, Zwolak, and Leak; Peer-reviewed, doi.org/10.1119/perc.2025.pr.Barru

I. INTRODUCTION

The lab coordination team for the Introductory Physics Labs at The University of Colorado - Denver (UCD) is interested in the comfort the teaching assistants (TAs) have with the content. This study is part of a broader project studying the transformation and efficacy of the labs. We seek to better understand how our TAs prepare, specifically in regard to their comfort with the material each week. We have designed and implemented weekly surveys over multiple semesters that involve both Likert style and free-response questions. These questions allow us to track the progression of TA comfort throughout the week, specifically (1) before the preparatory meetings, (2) after the preparatory meetings but before teaching, and (3) after teaching. The survey itself has dual purpose: to gather information to understand and determine a baseline for TA comfort with the content, and to elicit feedback from the TAs to improve the Labs and weekly preparatory meetings. So far in the Physics Education Research community there has been research into the efficacy of TA instruction [1–5] and preparation of TAs [1, 4–10], but how TAs feel about the content they are teaching and their comfort with that content is understudied. Rather than assuming our TAs are comfortable, we wish to establish the baseline level of comfort for our TAs and study changes to this over time.

Our survey measures self-reported TA comfort with content; no distinction was made for the participants in terms of subject content knowledge or pedagogical content knowledge and there were no conversations between the authors and the TAs about what "comfort with the content" means. We are not equating comfort with content to be the same as preparation; this pilot survey is to see if we get a signal of TA comfort throughout the week. In this paper we are working with the 'colloquial' definition of comfort: "contented well being" [11]; data from the free response questions indicate that TAs are responding in a way that is consistent with this definition, such as: "Having taught this lab multiple semesters, I felt very comfortable going into this lab."

A. Our Labs

The UCD physics department has reformed the Introductory Physics Labs over the past several years. The lab curricula is divorced from the lecture classes (the labs are not corequisites of lecture), but the experimental content roughly matches traditional content: Physics 1, "Mechanics", and Physics 2, "Electricity and Magnetism". The 13 weeks of lab content are shown in Table I. The reformed labs demand high levels of decision making in all aspects of the experiment from planning and design, data collection and reporting, and data analysis and discussion. This is achieved through a guided-inquiry model [12] where the instructional team of one TA and two Learning Assistants (LAs) [13] engage in Socratic dialog, but students have the agency to make their own choices. This team is further supported by the lab coordination team consisting of the faculty coordinator, facility coordinator, and head TA, a position filled by an experienced TA from the labs. The new structure of the labs is in line with the recommendations of the American Association of Physics Teachers Committee on Laboratories report [14] and guidelines set out by Redish [15].

The head TA and the faculty coordinator, the authors, run weekly preparatory meetings for the TAs. These meetings have two parts: 30 minutes of upcoming logistics and TA questions, and 60 minutes of content preparation for the following week. The head TA and faculty coordinator alternate running Lab 1 and Lab 2 content meetings so all TAs regularly have meetings with both members of the instructional team. During the content portion of the meetings, TAs are guided through the labs with a focus on the content and skills developed in that week. PowerPoint slides that organize lab time and structure full class discussions are made available in advance and their use is modeled in the content meetings. We discuss questions that may address potential student issues, take sample data to simulate the student experience, come to a consensus on grading priorities, and talk through potential student difficulties that may arise in class. TAs are expected to have read through all of the upcoming materials before the meetings and come prepared with notes and questions.

TABLE I. Weekly Lab Activities

Week	Lab 1	Lab 2
1	Measurements	Electroscope I
2	Pendulum I	Electroscope II
3	Pendulum II	DC Circuits I
4	Pendulum III	DC Circuits II
5	Pendulum IV	Nichrome Wire
6	Springs I	Lightbulb I
7	Springs II	Lightbulb II
8	Practicum	Practicum
9	Make-up week	Make-up week
10	Free Fall I	Magnetic Fields I
11	Free Fall II	Magnetic Fields II
12	Rotational Motion	Optics I
13	Accelerating Cart	Optics II

B. Our TAs

The distribution of new and returning TAs for our labs can be seen in Table II; switching TAs are returning TAs that moved from teaching Lab 1 to Lab 2 or the reverse and as such do not add to the total number of TAs in Semester 2. In Semester 1, the only TAs teaching content that was new to them were the new TAs while in Semester 2, 50% of the TAs were teaching new content.

Historically the TAs for the introductory labs at UCD are

TABLE II. New and Returning TAs

	New TAs	Returning TAs	Switching TAs
Semester 1	4	6	0
Semester 2	1	9	4

undergraduate students. In this work, we choose to refer to them as TAs, not as undergraduate teaching assistants (UTAs). This is because our TAs function as graduate TAs (GTAs) in our undergraduate only department, and there is no clear definition of UTA [16] in the literature that aligns with the role of our TAs. Several different models of UTAs have been put forth that range from a peer mentor with little to no pedagogical training or support [16, 17] to something more resembling an LA at UCD. The LAs in our labs consist of undergraduate students only; they are in all class sections and hold office hours, but are not involved in grading and are not responsible for logistics or classroom management.

Our TAs are typically undergraduate students serving as the instructor for the course. Their role includes:

- managing the Canvas site and posting materials
- grading weekly lab notebooks, pre/post lab quizzes, and the Practicum
- facilitating student learning in class using guided-inquiry and active engagement techniques
- holding weekly office hours outside of class
- leading a team of two LAs during class

There is plenty of research into the efficacy and preparation of GTAs as cited earlier, but relatively little into UTAs, especially UTAs functioning as GTAs. We hope that this work can add to the literature on GTAs and UTAs, establishing foundational knowledge that can be used to further support student instructors. To this end, we ask the following overarching research question: **How comfortable are TAs with the content they teach?** We further distinguish three sub-questions:

1. Does this change over the course of the semester?
2. Does this change based on the preparatory meeting? If so, how?
3. Does this change after TAs interact with students (teach)? If so, how?

II. DESIGNING THE SURVEY

The TA survey was designed with two goals in mind, the first is to establish a baseline for TA comfort and any changes due to preparation and teaching - see the research questions above. The second goal of the survey is to elicit feedback to improve the preparatory meetings. Individual responses to the free-response questions each week were anonymized and shared with the faculty coordinator to allow for rapid implementation of support for TAs and appropriate changes to the weekly preparatory meeting. Since the faculty coordinator is their instructor and supervisor, we hoped that anonymizing the responses would encourage the TAs to respond authentically and without fear of judgment.

The survey was built in Qualtrics and links were sent each week to the TA team. For the first semester, there was an initial version of the survey that began in the fourth week of the semester, and an updated version that began in the seventh week. Only minor revisions from that second version were made for Semester 2 when surveys started in the first week; the head TA also took the survey twice in Semester 2, once for Lab 1 and once for Lab 2. Informed consent was gathered for all respondents.

A. Survey Questions

The questions fall into 5 categories: (1) comfort at different times throughout the week, (2) helpfulness of the preparatory meeting, (3) personal preparation outside of the meeting, (4) reflection on personal preparation and the meeting, and (5) extra information. The extra information is specific to the intro lab courses at UCD. The present work focuses on the results of the first category, TA comfort throughout the week. These results come from the first Likert style question on the survey that is split into five parts, "How comfortable were you with the content for this lab...":

- **Q1.1**: ... before you did any preparation?
- **Q1.2**: ... after the preparatory meeting on Monday?
- **Q1.3**: ... after the meeting and your personal preparation?
- **Q1.4**: ... after teaching your first or only section this week?
- **Q1.5**: ... after teaching your last section this week?

The survey included several additional questions that are not analyzed in the present work.

III. RESULTS AND ANALYSIS

Table III shows the average, maximum, and minimum number of survey responses by semester. There were six TAs for Lab 1 and five TAs for Lab 2 both semesters, however there were only ten TAs total: the head TA teaches one section each of Lab 1 and Lab 2. In Semester 2 the head TA responded to the survey twice: once each for teaching Lab 1 and Lab 2, but only responded once in Semester 1.

TABLE III. Survey response N values

	$N_{average}$	N_{max}	N_{min}
Semester 1	7	10	3
Semester 2	9	11	6

If any responses were incomplete, meaning TAs submitted partially completed surveys, the partial responses were eliminated when looking at the averages and shifts below. The

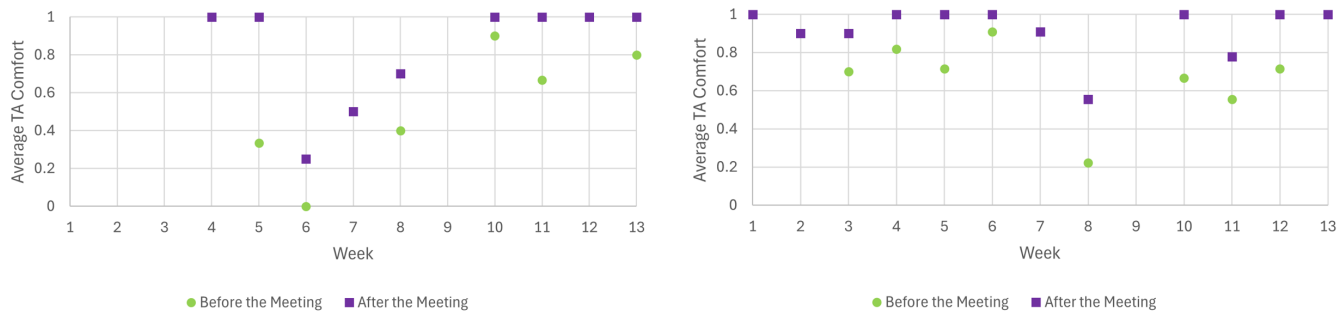

FIG. 1. Average comfort before and after the weekly preparatory meeting. Left: Semester 1, Right: Semester 2 Note: the survey did not begin until week 4 of Semester 1 resulting in missing data in this figure for weeks 1-3 and that week 9 is a makeup week with no specific content. On either plot when only one point is visible, average comfort level was the same before and after the meeting.

Likert responses were collapsed and given a value of 1 for comfortable (very or somewhat), 0 for neutral, and -1 for uncomfortable (very or somewhat). Responses were averaged across all TA responses, no separation for Lab 1 or Lab 2. Analyzing differences between labs is a topic for future work.

To assess TA comfort with content, we focus on responses to four of the five sub-parts of the first survey question: **Q1.1**, **Q1.2**, **Q1.4**, and **Q1.5**. Figure 1 shows average TA comfort both before and after the preparatory meetings for Semester 1, left, and Semester 2, right. The vertical axis on this plot is truncated: it could show -1 to 1, the full range of possible comfort. Instead we chose to highlight the interesting result that all of the values are positive and set the range from 0 to 1. Each point on the plots is the averaged comfort for all TAs, both Lab 1 and Lab 2, each week. While average TA comfort is always positive at every point measured in the week, there are individual negative values in the data. There are no weeks in Fig. 1 where average comfort decreases due to the meeting; for all weeks self-reported comfort is positive and frequently high. The exception to this is week 6 in Semester 1 when the faculty coordinator was unable to run one of the preparatory meetings due to illness, however it also has $N = 4$, well below $N_{average}$, which may have impacted the data.

Most weeks show an increase in comfort, with three weeks in Semester 1 (weeks 4, 7, and 12) and four weeks in Semester 2 (weeks 1, 2, 7, and 13) showing no shift in average comfort from the meeting. For the weeks showing a positive shift, the largest shift is in week 5 of Semester 1 which may be partially due to $N = 3$, the lowest response rate of the study, and also partially due to the introduction of a completely new activity in Lab 2; the TAs for Lab 2 had never seen or taught the material before, so low initial values and a large post-meeting shift is reasonable.

Week 8 is the administration of the Practicum, an assessment implemented for the first time in Semester 1. The Practicum is aimed at measuring students' practical laboratory and data analysis skills in a context similar to what they have seen throughout the semester. The Practicum was a new and unfamiliar assessment method for the TAs in Semester 1; the large shift in comfort after the meeting is consistent from Semester 1 to Semester 2, indicating this is consistently an uncomfortable week for TAs before the meeting.

In both semesters we see high comfort in weeks 9-13; this is not particularly surprising given that there is relatively little new content in these weeks. The exception to this is week 11 of Semester 2 when the activity for Lab 1 was given a new framing to address past struggles; here we see that this week's average comfort, both before and after the meeting, are lower than the surrounding weeks and the shift is smaller.

A. Shifts in TA comfort

To address Research Questions 2 and 3, we focus now on shifts in TA comfort following the prep meeting, Fig. 2, and following teaching, Fig. 3. These plots show the average of the shifts for individual TAs, not the shift in averages, separated by week. In Table IV, we report the overall shifts, averaged across all TAs, weeks, and semesters.

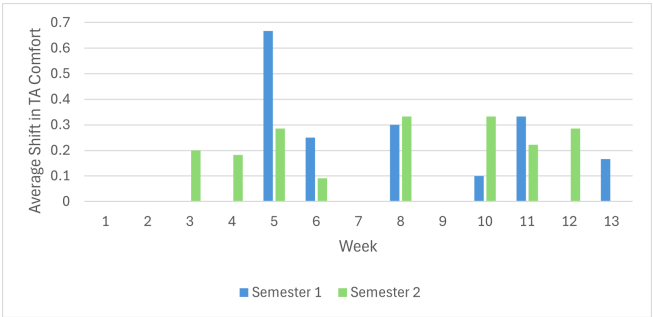

FIG. 2. Shift in TA comfort from before to after the weekly preparatory meeting. In Semester 1 there is no data for weeks 1-3, additionally there are no shifts in weeks 4, 7, and 12. Week 9 is a makeup week with no specific content and is the only week aside from week 7 that shows no shift in either semester.

The shift in comfort after the meeting is always positive: comfort is always the same or higher after the preparatory meetings and frequently all TAs report positive comfort, average = +1, after the meetings. There is a large shift in

Semester 1 week 5. As stated above, this week was a new activity and had low N both of which most likely contributed to this large shift. It is interesting that across both semesters, week 7 shows no shifts from the preparatory meeting. This lab activity is the second week of a two-part lab, but as shown in Table I it is not the only week with similar content to the prior week. We will focus on week 7 in future semesters as data collection continues.

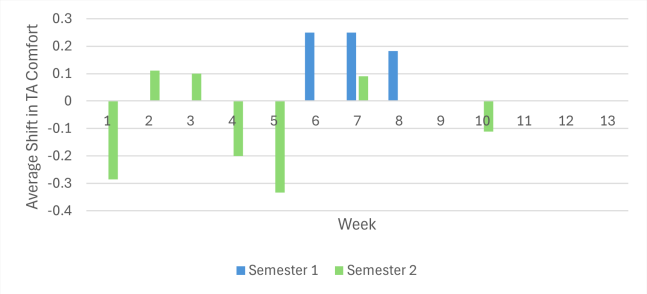

FIG. 3. Shift in TA comfort from after the weekly preparatory meeting to after teaching. In Semester 1 there is no data for weeks 1-3; all other "missing" bars are shifts of 0. Week 9 is a makeup week with no specific content.

In contrast to the preparatory meetings, Fig. 3 shows shifts are both positive and negative after teaching. In Semester 1 we have mostly no shifts in average comfort from after the meeting to after teaching, possibly due to 80% of the TAs teaching content they had seen before as either a returning TA (see Table II) or a TA who had previously been an LA for the labs. The positive shift in week 6 of Semester 1 may be related to the initially lower comfort and a less effective preparatory meeting due to illness as discussed above, since this shift was not seen in Semester 2. We do not see similar shifts after teaching in week 8; this is the Practicum week, and TAs reported feeling more comfortable after administering the practicum which implies that their decreased comfort after the meeting may have been due to the unfamiliar nature of this new assessment in Semester 1.

Semester 2, in Fig. 3, shows negative shifts in comfort from after the meeting to after teaching in weeks 1, 4, 5, and 10. This implies that while the meeting improved comfort, actually teaching lowered comfort. This may be due to 50% of TAs teaching new content, see Table II, leading them to recognize that they were not as comfortable with the new material as they had thought before teaching it.

From Table IV we see that there is a 22% average positive shift in comfort after the meeting. This is substantial, especially when we consider that the average comfort before the meeting left a maximum possible positive shift of 36%. Cohen's d is approximately 0.5 for the shift from the meeting, a medium effect, and 0.15 for the (magnitude) shift from teaching, typically considered a small effect. The shift and effect size show that our preparatory meetings lead to consistent and substantial increases in TA comfort. The effect of teaching is less clear. Even though a Cohen's d of 0.15 is usually considered "small," we still find this to be a meaningful effect, especially since the high levels of post-meeting comfort, as seen in Fig. 1, create a notable ceiling effect effectively eliminating the possibility of positive teaching shifts in many weeks.

TABLE IV. Average Shifts in TA Comfort. Dashes indicate that the value is unchanged from the cell above.

	After meeting	**After teaching**
Average shift (raw)	0.16	0.0057
Average shift (magnitude)	-	0.085
Percent shift (raw)	22%	0.63%
Percent shift (magnitude)	-	10%

IV. CONCLUSIONS AND FUTURE WORK

In this preliminary study we have shown that even without an operational definition of TA comfort, our survey does provide a signal of comfort and changes over time in line with the 'colloquial' definition of comfort. The present analysis provides clear answers to the first two research questions. We have found that the baseline for our TA comfort is high, with average TA comfort before the meeting usually above 0.5 and never negative. We have also found that there are substantial positive shifts in TA comfort following the preparatory meetings. These shifts are roughly stable throughout the semester, with an average positive shift of 22%. The effect of teaching on TA comfort is less clear: with an average raw shift of 0 but an average magnitude shift of 10%. This indicates that classroom experience has both positive and negative effects on comfort, but with roughly equal amounts. However, we note that the high comfort after the meeting may obscure *increases* in comfort after teaching - addressing this possible ceiling effect is an avenue of future work.

Currently planned work will complete the analysis of the remaining survey questions. In future semesters, we expect to expand the survey to better define overall TA comfort with content knowledge versus pedagogical content knowledge and implement it at multiple institutions. We will continue data collection with an eye towards the development of a working definition of 'TA comfort' that is situated in the PER literature.

ACKNOWLEDGMENTS

We would like to thank Samantha Pettus, our facility coordinator, and Bethany Wilcox for her support and feedback. This work was not supported by a specific grant from any funding agency, thanks to the UCD physics department for providing travel and conference funds.

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