Exploring Graduate Teaching Assistants' Teaching Practices in a Purposefully Designed Active Learning Environment

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This study explores the instructional practices of four graduate teaching assistants (GTAs) – Ursula, Ava, Phoenix, and Cole – in an active learning Calculus I course. Each GTA's unique pedagogical background is discussed in relation to their teaching methods and their students' classroom actions. Ursula, a seasoned high school math teacher, brings a wealth of experience in active teaching, while Ava, having encountered active learning as a student, reflects on her positive experiences. Phoenix, a novice GTA, emphasizes group work and individual student exploration, while Cole, with limited teaching and active learning experience, promotes student independent work. The contrasting approaches of these GTAs within the same purposefully designed active learning environment provides valuable insight into the connection between previous educational experiences and teaching practice, especially with respect to student engagement in a Calculus classroom.

Keywords: Active Learning, Calculus, Teaching Practices, Graduate Teaching Assistants

Calculus teaching and learning is an important and much-discussed topic in post-secondary mathematics education. Many educators and administrators are concerned about high DFW (the percentage of students who receive a D, an F, or withdraw) rates in introductory mathematics courses. Up to 50% of students nationally fail their first mathematics course, and 50% of students who struggle in mathematics courses in their first year leave STEM majors (APLU, n.d.). One way that institutions have attempted to combat these high DWF rates is through the introduction of active learning into first-year mathematics courses (APLU, n.d.). The Conference Board of the Mathematical Sciences (CBMS) defines active learning as "classroom practices that engage students in activities, such as reading, writing, discussion, or problem solving, that promote higher-order thinking" (CBMS, 2016, para. 1). Building on this, we define active learning as a productive learning environment that provides meaningful mathematical learning opportunities for all students. Such active learning environments include three key components: the inclusion of cognitively demanding mathematical tasks, the delivery of high-quality mathematics instruction, and the promotion of both small and whole-group discussions.

While much of the focus of active learning is on students – especially engagement and higher-order thinking – active learning also requires instructors to take on a prominent role. This role differs significantly from a traditional role in a lecture-based classroom. Instructors must choose rich tasks which promote higher-order thinking, facilitate classroom discussions, and manage a classroom in which student-centered activities occur. This shift often presents a challenge, as most university instructors have not experienced this type of classroom in either prior professional settings or their own education.

At large universities, Graduate Teaching Assistants (GTAs) are a significant part of the implementation of active learning. Consequently, there has been a push to provide GTAs with professional development opportunities to help them make the transition to facilitators of active

learning in their classrooms (Deshler et al., 2015). Significantly, "effective training of graduate teaching assistants" is one of the seven characteristics of a successful calculus program, as put forth by Bressoud and Rasmussen (2015, p. 145). GTAs have an important role in implementing student-centered pedagogy and active learning. Therefore, it is important to understand how the GTAs themselves enact and support active learning in the classroom. It is particularly important to understand how their backgrounds may influence their actions. This leads to the question we explore in this study: what teaching actions do GTAs with different pedagogical backgrounds take in an active learning Calculus I course and how do they discuss these actions?

Literature Review

Because of the current focus on student-centered activities in entry-level mathematics classes, much has been written on active learning strategies and their effect on student learning (Freeman et al., 2014; Kim et al., 2013). As GTAs play an important role in enacting active learning, there has been a focus on GTA professional development (PD). GTA PD programs provide an important opportunity for GTAs to engage with and understand research-based instructional strategies, including exposure to active and student-centered pedagogy (Archie et al., 2022, Deshler et al., 2015). Many GTAs come into programs with little to no teaching experience, and both pedagogical content knowledge and knowledge of student thinking are important for GTAs' transition from learner to teacher (Kung & Speer, 2009). GTA PD provides them with opportunities to develop this knowledge and connected skills.

Regardless of whether they have participated in a PD program, GTAs may not have experienced active-learning approaches as learners in their own coursework, leading to a limited comfort with using these approaches in their teaching (Deshler et al., 2015). Patrick et al. (2021) studied GTAs across a College of Science and College of Engineering to determine their perceptions and practice of active learning strategies as a student and teacher. They found that GTAs' ranking of teaching strategies changed depending on whether they were thinking about their learning or their teaching. "TAs were currently teaching differently from the way they preferred to learn and how they thought undergraduates learned best" (Patrick, et al., 2021, p. 11). GTAs reported a desire for more active learning strategies in their own classes and felt that they should use more active learning strategies in their own teaching (Patrick, et al., 2021). However, GTAs' feelings about active learning were not sufficiently reflected in their classroom practices. While the link between experience and teaching practices seems to be straightforward, empirical evidence on mathematics GTAs' implementation of active learning based on their perspectives about and background with active learning is sparse.

Even experienced instructors can encounter challenges when implementing active learning strategies, requiring deep understanding of effective teaching practices and productive pedagogical strategies. The Mathematics Association of America National Study on College Calculus calls teaching which incorporates active learning ambitious teaching, stating that "they are ambitious in the sense that they require substantial institutional supports and advanced knowledge, skills, and beliefs on the part of instructors" (Larsen et al., 2015, p. 104). These complexities in implementing active learning also affect GTAs, who play pivotal roles in undergraduate mathematics courses. GTAs, often lacking training and prior classroom experience, face these challenges despite the growing emphasis on active learning in undergraduate mathematics education, as their own exposure to active learning is limited

(Manzanares et al., 2023). Therefore, we need studies that focus on GTAs conceptions and teaching practices of active learning.

Methods

Active Learning Context

This study takes place within a wider research effort to transform introductory courses in STEM at a large public university in the northeast USA. This study represents one component of the overall project and examines the actions and ideas of GTAs as they integrate active learning into their Calculus I teaching. The course follows a lecture-recitation model of instruction in which students attend a large lecture (~150 students) taught by a faculty member and a smaller recitation (~20 students) taught by a GTA. Implementation of active learning was purposefully focused on recitation sections and included a new classroom structure (introduction, small group work, class discussion), researcher-designed activities, and near-peer tutors called Learning Assistants (LAs). GTAs were given the freedom to implement these active learning methods in whatever way they saw fit.

While all recitations involved active learning, there were six special researcher-designed activities spread over the course of the 15-week semester. These activities were designed to foster the core practices of quantitative reasoning (Thompson, 1994) and representational fluency (Fonger, 2019). Students worked on these activities in small groups of three to four students, supported by the GTA and LA. The GTA was responsible for leading the class, meaning they facilitated the introduction and class discussion and were responsible for administrative tasks such as proctoring quizzes and collecting homework. The LAs' responsibility was to facilitate small group discussion, typically by asking students questions and attending to student ideas.

Data Collection and Analysis

Data for this study includes video recordings of recitation sessions and interviews with GTAs. Recitations were recorded six times throughout the semester on the days the researcher-designed activities were implemented. Structured interviews with GTAs were conducted at the beginning and the end of the course and were focused on GTAs' experiences with and ideas about active learning. This analysis focuses on a subset of these recordings for four GTAs. These four GTAs were selected for this analysis because they highlight distinct ways in which classroom actions and conceptions of teaching manifest in this active learning context.

To capture the classroom actions of these GTAs across the semester, two video recordings (one from the first half of the semester and one from the last three weeks) were analyzed for each GTA using the Classroom Observation Protocol for Undergraduate STEM (COPUS) (Lund et al., 2015). The COPUS framework describes the types of activities both instructors (Figure 1) and students (Figure 2) are engaged in throughout a lesson. Codes from this framework were applied to every two-minute interval of the recorded video. For each GTA, the codes were aggregated across the two videos, and the percentage of each coding category out of total number of codes was calculated. For robust descriptions of the COPUS action codes used in this study see Lund et al. (2015). Each lesson was coded by at least two members of the research team and disagreements were resolved by consensus of the team.

Interviews were analyzed in order to contextualize each GTAs' conceptions of their practice in the reformed classroom. These interviews were analyzed through open coding and thematic analysis to capture GTAs' definitions of and experiences with active learning (Miles et al., 2018; Strauss & Corbin, 1998).

Results

In this section, we will introduce the background of four GTAs, Ursula, Ava, Phoenix, and Cole, compare their instructional actions (Figure 1), and examine the classroom actions of their students (Figure 2). We aim to understand the teaching approaches adopted by the GTAs with diverse pedagogical backgrounds and explore how they discuss these actions.

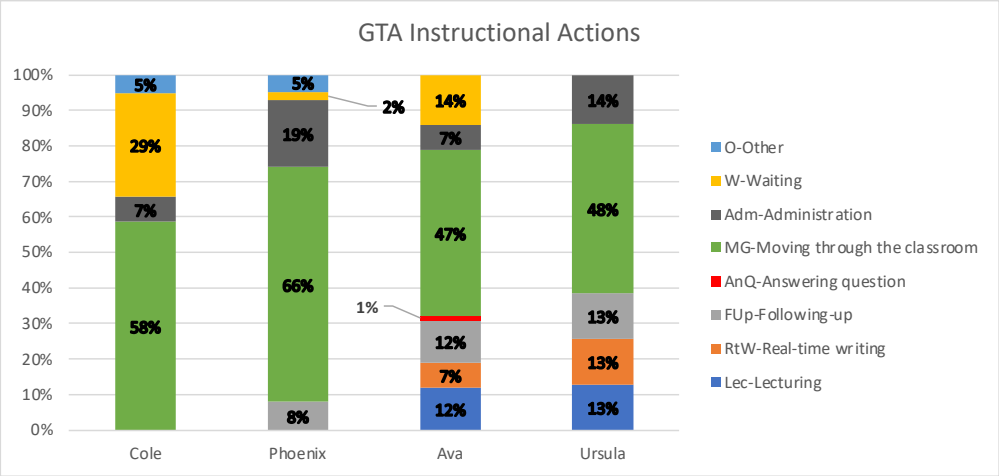

Figure 1: Instructional Actions of each GTA

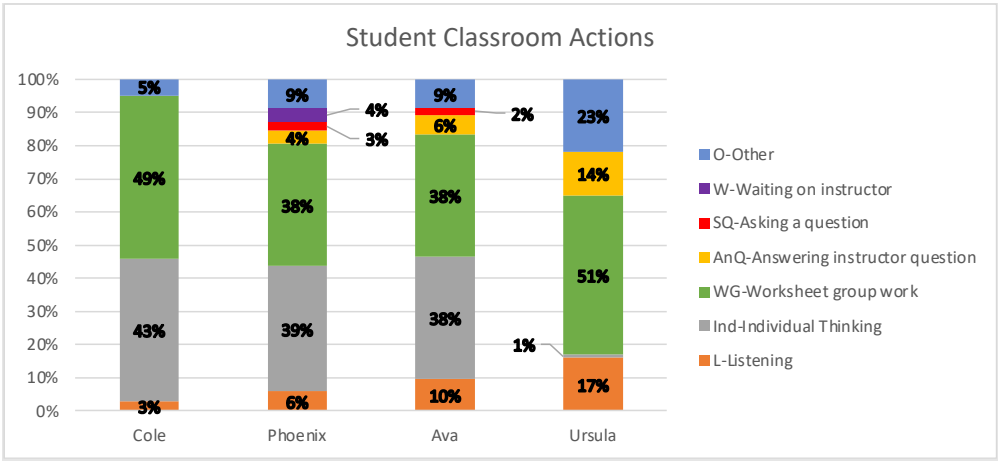

Figure 2: Actions of Students in each GTA's classroom

Ursula

Ursula was a graduate student in the Mathematics Education Ph.D. program and in her fifth year as a GTA at the university. Prior to her GTA experience, Ursula had substantial experience teaching mathematics to high school students. She described her high school teaching practice as "active" and said that she often had students work in groups or work independently. In Figure 1,

we see that approximately half of classroom action codes are *moving*, meaning that she devotes significant attention to facilitating student work on activities in the classroom. She described that, when she moves through the classroom, "I'm not going to solve the activity for them, but if they got stuck I will ask them the question to lead them to the next step".

Outside of facilitating group work, Ursula's actions are still notably student centered; 13% of her actions were coded as *following-up,* meaning that she responded to student ideas in front of the class. Even though 12% and 13% of her actions are respectively focused on *lecture* and *real time writing*, these codes primarily occur during the lesson introduction. Ursula explained that, in this introduction, she "reviews concepts" and "examples" to make students more "comfortable" participating in group work by fostering "confidence" in their mathematical knowledge. While lecturing and writing are not typically considered as active, Ursula used them selectively and strategically in her teaching to support the more active portions of the lesson and to create a "balance between the instructors and the student". While a significant number of codes were *administration,* even these actions were frequently student-centered, consisting of such things as organizing student groups and assigning students problems to write on the whiteboard.

This emphasis on group engagement and instructor collaboration was also reflected through the actions of students in Ursula's classroom (Figure 2). Her students' actions were primarily worksheet *group work,* indicating that students typically worked together on class activities. Also, the students in Ursula's classroom were *answering instructor questions* (14%) and *listening* (17%) meaning that they shared their ideas in front of their peers and listened to one another and to Ursula. The *other* (23%) category in this case represents students writing work on the classroom whiteboards, again emphasizing the opportunities for students to share their mathematical ideas in this classroom.

Overall, Ursula's conceptions and practices typify how a GTA with previous active-learning teaching experience was able to effectively implement such methods at the undergraduate level and provide reasons why such methods are appropriate for supporting student learning.

Ava

Ava was a mathematics Ph.D. student who at the time of the study was in her third year as a GTA at the university. Unlike Ursula, she had no previous independent teaching experience, but Ava did encounter active learning several times as an undergraduate student. She described that she "struggled" to interpret mathematical content independently as a learner in a flipped classroom, but she had more positive experience in a class where "the teacher would present the material, and then we'd work on it in groups".

In her own practice as a GTA, Ava's actions as a teacher mirror her positive experiences as a student. We see that her actions as a teacher are similar to Ursula's (Figure 1), but 14% of Ava's actions are *waiting,* meaning that she was merely standing on the side during class time. This presence of wait time could be because Ava frames active learning as "when students bounce ideas off of each other" and hinges upon "the student thinking more deeply about the topic". Since student thinking is central to active learning in her view, Ava allowed students time to work on their own without her intervention.

Additionally, we see that Ursula and Ava's students primarily engage in the same types of activities (Figure 2), except that Ava's students engage in *independent thinking* (38%) while Ursula's students rarely work independently. Again, this is probably rooted in their different conceptualizations of active learning; Ava has a broad view of active student engagement while Ursula takes group work as essential in such an environment.

From Ava's actions and discussion of these actions, we see that she used her own experiences as a student with active learning to guide her teaching as a GTA in an active environment. Because of her own positive experiences with group work and guided work during class, she implements such practices in her classroom, supporting students to work in groups or independently on classroom activities.

Phoenix

Phoenix was a graduate student in the mathematics education PhD program; in her second semester as a GTA. She began the graduate program directly following her undergraduate degree at the same institution, meaning that she had no independent teaching experience prior to her time as a GTA. She did, however, have experience as a peer-tutor and had taken several university-level courses focusing on teaching and learning.

Phoenix's teaching actions are notably distinct from the relatively similar pattern seen in the actions of Ursula and Ava. Unlike these two, Phoenix did not lecture or write on the board; she was mostly involved in *moving* (66%) and *administration* (19%). That is, Phoenix's classroom actions primarily focus on working with students and organizing student groups, rather than instructing students from the board. This is reminiscent of her own experiences with active learning as a student as she and her peers spent time "working in groups and kind of investigating the material ourselves". She further explained that she views active learning as rooted in "the students and the students wanting to learn the material" with her role being to "help each individual student" through this process. Phoenix recognized her responsibility as an instructor to guide student thinking, but she provided this support at an individual and group level, while Ursula and Ava provided support at the classroom level through short periods of direct instruction at the board.

While Phoenix's actions are distinct from Ursula and Ava's, we see that her students' actions are relatively similar to Ava's students (Figure 2). We do see that Phoenix's students are *listening* less than Ava's students (6% vs 10%), which reflects Phoenix's emphasis on group work time. Similar to Ava, we see that Phoenix's students had the opportunity to share their thinking as they are engaged in *asking questions* and *answering instructor questions.*

Through these actions and commentary, we see that Phoenix's status as a novice GTA with limited active learning experience led to a strong emphasis on group work in her classroom. While Ava and Ursula, who have more experience with active learning, chose to provide their students with some direct instruction, Phoenix chose to provide students more time to work on their own or in groups. While this alternate focus in teaching actions was not coupled with major shifts in student actions, these alternate approaches of GTAs in the same environment are notable.

Cole

Cole was a first-year Ph.D. student in statistics and, like Phoenix, was in his second semester as a GTA at the university. Cole had some online experience as a one-on-one tutor before his time as a GTA, but, unlike the other GTAs discussed in this study, he had no experience with active learning as a teacher nor as a student. He stated that in his time as a student he would "pretty much study alone, individually" and "usually just listen to the teachers and copy, paste" notes written on the board.

Accompanying this difference in experience, we see that Cole's classroom actions were distinct from those of Ursula, Ava, and Phoenix. While Cole's proportion of *moving* is similar to

the other GTAs, he has a much higher proportion of *waiting* (29%) than the other GTAs. It is also important to note that Cole's *other* code marked times when he left the classroom entirely, contrary to other GTAs for whom the *other* code was content related, representing such activities as discussing study skills and reviewing student work. Again, these actions reflect Cole's view of active learning; he describes active learning as "communicating with others... exchanging your thoughts" making his role in the classroom "more like a tutor". Cole's actions are consistent with this idea of active learning as he lets students work with a high degree of independence and intervenes in this process sparingly. This strong emphasis on student independence could also be a reactionary effort to move away from his "copy, paste" experience as a learner.

Similarly, we see differences in the actions of Cole's students in comparison to the students of the other three GTAs. Cole's students are almost always engaged in *worksheet group work* or *individual thinking* (92%). Again, this echoes Cole's conceptualization of active learning as students working without much direct instruction.

Overall, Cole's actions show one way in which active learning can be enacted by a GTA with little prior experience with such methods as a student or as a teacher. In Cole's classroom, active learning manifests as student independence, with Cole offering students support at the individual or group level, rather than providing direct instruction.

Discussion

From the four GTAs examined above, we see that there is a connection between previous active learning experiences and instructional practices. Ursula, a GTA with experience teaching in an active learning setting, gives attention to students' work within groups, but supports this work through some direct instruction and following up on group work in front of the class. Ava and Phoenix, who had some experience with active learning as students, still emphasize group work, but allow students to work individually. Cole, a GTA without previous active learning experience, attends solely to group work, occasionally leaving students to their own devices.

While all GTAs in this study were provided with the same active learning teaching guidelines and supports (i.e., LAs, researcher-designed activities, suggested classroom structure), we observe that GTA actions and the actions of their students are distinct within each classroom. Previous literature acknowledges the need for GTAs pedagogical training, but we emphasize that GTAs educational needs as teachers vary depending on their previous experiences as both teachers and learners. That is, "effective training" (Bressoud & Rasmussen, 2015, p. 145) of GTAs must account for the lived educational experiences and resulting pedagogical ideas of GTAs. Without such background taken into account, GTAs may have difficulty implementing active learning practices in the classroom.

Since GTAs often serve important roles in facilitating student-centered instruction within Calculus courses, it is important to acknowledge factors which enable or inhibit them accomplishing this type of instruction. Here, we identify background experiences with active learning as one such factor and encourage both researchers and educators to pursue practical means of integrating GTAs' previous educational experiences into GTA pedagogical training.

Acknowledgments

This research was supported by the National Science Foundation, Award No. 2013427. The opinions expressed herein are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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