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Journey to becoming a culturally responsive science educator: reflections about use and barriers from graduate teaching assistants at a Minority-Serving Institution

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Introduction: A pedagogical framework with the aim of dismantling sociostructural disparity and systemic oppression is culturally responsive science teaching (CRST). Although CRST has been linked with improved student empowerment, self-efficacy, and ethnic and academic identity, more research is needed to assess whether graduate teaching assistants (TAs) in college science are familiar with and prepared to engage in CRST. We conducted two training sessions for inclusive teaching practices and CRST during a graduate TA teaching professional development course at a research-intensive Minority-Serving Institution (MSI).

Methods: We collected surveys, written reflections, and session artifacts from five graduate TAs participants and used qualitative methods to generate an understanding of their experiences with inclusive teaching and CRST.

Results: Results from this exploratory study indicated that graduate TAs felt they lacked training in inclusive practices and CRST, but still were intentional in providing their students with individualized attention and tried to make sociopolitical connections in their teaching. Also, they reported using inclusive practices and CRST by encouraging shared student experiences and promoting growth mindsets. A lack of time and training remained a barrier to implementation.

Discussion: These findings can inform future inclusive teaching professional development, which aims to bolster instructor's inclusive and culturally responsive science teaching practices, especially at MSIs.

KEYWORDS

graduate students, culturally responsive pedagogy, inclusive teaching practices, equity, equality, qualitative methodology, professional development

1 Introduction

The exclusion of members from diverse groups in science, technology, engineering, and mathematics (STEM) fields has been, and continues to be, detrimental in many ways and is often linked to discriminatory treatment in higher education and STEM professions (Gibbs and Marsteller, 2016). For example, at both undergraduate and graduate levels, Persons Excluded because of their Ethnicity and Race (PEERs; i.e., people identifying as Hispanic or Latino, Black or African American, and American Indian or Alaska Native; Asai, 2020) face limited entry into STEM fields and evince unacceptably high rates of attrition (Chen, 2013; Marín-Spiotta et al., 2020; Sowell et al., 2015; Barthelemy et al., 2016; National Academies of Sciences, Engineering, and Medicine, 2020; Posselt, 2021; President's Council of Advisors on Science and Technology, 2012). As such, higher education reflects a context that denies opportunities through practices and policies (i.e., structures) that inhibit the talent development of PEERs (McGee, 2020). Historical patterns of entry into STEM fields (proportionally low), lack of representation of students, faculty, or staff "who look like me," and low quality of sociocultural and academic support in and out of the classroom (e.g., non-response to bias incidents, poor mentoring, reduced funding for professional development) are key elements in the challenging context that is faced by PEERs in pursuit of advanced study in STEM (National Academies of Sciences, Engineering, and Medicine, 2016; Leath and Chavous, 2018; McGee, 2020; McGee and Robinson, 2019).

Individuals with authority, power, or influence within the academic structure have the potential to enact change to combat these structural inequalities. One potential avenue of influence is through graduate teaching assistants (TAs), graduate students who personally teach and interact with undergraduate students, typically by teaching lab or discussion sections in STEM. However, most STEM instructors have no to little formal training in teaching (Brownell and Tanner, 2012), let alone training in best practices related to inclusion or cultural awareness (Dewsbury, 2017). The lack of training applies to not only faculty, but also graduate TAs (Gardner and Jones, 2011; Tanner and Allen, 2006). As a result, graduate TAs often draw upon their experiences as students and replicate the teacher-centered and exclusive teaching practices modeled to them by STEM faculty who have significant influence on their careers (Seymour, 2005).

Meanwhile, graduate school is an optimal place to incorporate inclusive science teaching. Graduate TAs have more contact with undergraduate students and should be considered key contributors to learning outcomes through their potential to create inclusive and equitable classroom environments (Harper et al., 2019; Kendall and Schussler, 2012). Previous studies have found the important role that graduate TAs play in supporting undergraduate academic success (i.e., consistently high or measurable improvements in learning, individual grades, grade point average, or increase in course pass rates over a specific time period) and STEM success pathways (i.e., marked increases in measures of enrollment, persistence, retention, and completion of degree and credentials in STEM field or employment in a STEM-related field; National Academies of Sciences, Engineering, and Medicine, 2019). In addition, training graduate teaching assistants provides a unique opportunity to potentially shape teaching practices in professionals at the start of their teaching career, which may have greater implications structurally over time. Training graduate TAs in asset-based teaching practices, including inclusive and culturally responsive science teaching, is one way that universities and academic programs can fight for social justice to advance equitable undergraduate academic success and STEM success pathways.

Training graduate TAs in asset-based teaching practices is of particular importance at Minority-Serving Institutions (MSIs), including Historically Black Colleges and Universities (HBCUs), Tribal Colleges and Universities (TCUs), Hispanic Serving Institutions (HSIs), and Asian American and Native American Pacific Islander Serving Institutions (AANAPISIs). Graduate TAs at MSIs play a critical role in training, educating, and mentoring PEER students in STEM disciplines (National Academies of Sciences, Engineering, and Medicine, 2019). For example, Gonzalez et al. (2020) found that graduate students saw their role as mentors to undergraduates at HSIs as essential, especially at large HSIs, where undergraduate students can easily get lost. Similarly, it has been shown that there are academic benefits, such as increased grades and performance, increased retention, and future course and major decisions, that occur when students and instructors, whether professor or graduate teaching assistant, share the same race, ethnicity, and/or gender (Oliver et al., 2021; Gershenson et al., 2016; Lusher et al., 2018; Price, 2010; Solanki and Xu, 2018; Egalite et al., 2015; Fairlie et al., 2014; Dee, 2005; Birdsall et al., 2020). While these benefits have been quantitatively observed under a variety of contexts, there is very little qualitative research explaining why these benefits occur. However, it stands to reason that at least some of the benefit comes from instructors being invested in their students and minimizing negative interactions, such as microaggressions, skills which asset-based teaching practices can help provide (Gershenson et al., 2016).

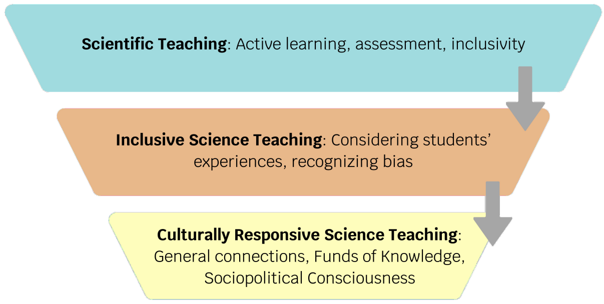

FIGURE 1
Proposed conceptual model relating the three theoretical frameworks guiding the present study, in which CRST is embedded within IST, and IST is imbedded with ST.

2 Theoretical frameworks

Our study is guided by three theoretical frameworks: (1) Scientific Teaching, (2) Inclusive Science Teaching, and (3) culturally responsive science teaching (Figure 1).

2.1 Scientific teaching

Scientific Teaching (ST) is a pedagogical framework (Handelsman et al., 2007; Pfund et al., 2009) which encompasses three elements: active learning, assessment, and inclusivity. Active learning refers to exercises in which students actively engage in an activity (e.g., writing, discussing, solving, or reflecting), rather than passively listening to a lecture. Assessment can be used during a learning event (formative assessment) or at the completion of a unit (summative assessment), in each case providing information to students and instructors regarding student progress. Inclusivity embodies the idea that undergraduate science courses contain students of diverse backgrounds and that conscious efforts are required to achieve course environments that minimize potential biases and promote the success of all students (Couch et al., 2015). Previously, the ST framework was used as the basis for faculty teaching professional development (Gregg et al., 2013; Durham et al., 2017, 2018, 2022); however, the Cotner group has been leading efforts using the ST framework for graduate teaching professional development (Barron et al., 2021; Patrick et al., 2021).

2.2 Inclusive science teaching

Despite development in ST, STEM instructors have been found to teach using mostly teacher-centered techniques that can lead to high failure rates (Freeman et al., 2014; Stains et al., 2018) and can perpetuate systematic discrimination of PEER students in STEM classrooms (Shukla et al., 2022; Theobald et al., 2020). As a result, there has been a movement to train instructors in Inclusive Science Teaching (IST; Dewsbury and Brame, 2019; Killpack and Melón, 2016; Dewsbury, 2017, 2019; Johnson, 2019; O'Leary et al., 2020; Siegel et al., 2022; Artze-Vega et al., 2023), equity pedagogies (Madkins et al., 2020), anti-racist pedagogies (Calliste and Dei, 2000; Cronin et al., 2021), and/or culturally responsive pedagogies (Gay, 2010; Ladson-Billings, 1995; Barron et al., 2021). One model of IST, based on Dewsbury's (2019) deep teaching model, comprises five key competencies: (1) self-awareness, (2) empathy, (3) classroom climate, (4) pedagogy, and (5) network leverage. The benefits students gain from instructors of IST are well-established, and include a higher sense of belonging, greater self-efficacy in the classroom, and increased motivation to engage in class (Zumbrunn et al., 2014; Dewsbury et al., 2022). Further, users of inclusive pedagogies may also reap benefits. For example, in crafting more inclusive learning environments for their students, IST instructors may gain empathy as they consider their students' lived experiences and challenges through engaging in perspective-taking. Additionally, in considering their students' needs, instructors often come to understand how their own identities and experiences impact their attitudes and teaching practices (Dewsbury, 2017). We believe these instructor-centered benefits can be instrumental in increasing awareness and understanding around issues of sociostructural disparity and systemic oppression for instructors (e.g., TAs) in STEM, particularly in instances where cultural dimensions are emphasized (Marchesani and Adams, 1992). In order to mitigate the effect of sociostructural disparity and systemic oppression of historically and currently excluded students in science classrooms, one must be active and intentional in dismantling structures of oppression. One pedagogical technique with this aim is culturally responsive science teaching (CRST), an approach based on student empowerment, cultural competence, and sociopolitical consciousness (Barron et al., 2021). Below, we elucidate the role of CRST in serving PEERs in higher education STEM.

2.3 Culturally responsive science teaching

Culturally responsive pedagogy has been found to be an important method for promoting student achievement and student engagement (Sleeter, 2012). According to Gay (2010), culturally responsive teaching improves students' academic achievements by presenting knowledge and skills in a way that is consistent with their own cultural norms and frames of reference. In a synthesis of culturally relevant education, Aronson and Laughter (2016) found that this approach increases student motivation, interest, ability to engage in content area discourses, perceptions of self as capable students, and higher test scores. O'Leary et al. (2020) engaged STEM faculty in multi-day culturally responsive teaching workshops focused on raising awareness of student and instructor social identities and exploring barriers to learning, such as implicit bias, microaggressions, stereotype threat, and fixed mindset. They found that faculty (1) increased their knowledge of identities and the barriers to learning in STEM classrooms, particularly those faced by students from underrepresented groups in STEM or socioeconomically challenged backgrounds; (2) changed their attitudes about students' abilities as science majors, shifting away from a fixed-mindset perspective in which characteristics, such as intelligence, are perceived as innate and unalterable; and (3) modified their teaching approaches to promote inclusivity and cultural responsiveness. Culturally responsive teaching, thus, affected STEM instructors' knowledge, attitudes, and actions around barriers related to underrepresentation. Most of the research on the benefits from using culturally responsive teaching has not reflected, let alone focused, on how or whether these outcomes specifically apply to instructors from diverse backgrounds, like graduate TAs at a Minority-Serving Institution. We believe that the latter may especially benefit personally from the practice of culturally responsive teaching. By reflecting on the barriers and challenges faced by their students, graduate TAs may come to achieve a better understanding of their own challenges, and we argue, gain tools to increase their resilience and success outcomes.

The model of culturally responsive science teaching (CRST) developed by Barron et al. (2021) draws on culturally relevant pedagogy (Ladson-Billings, 1995), culturally responsive teaching (Gay, 2010), funds of knowledge (Upadhyay, 2006; Moll et al., 2006), and sociopolitical consciousness or social justice science issues (Mensah, 2011; Morales-Doyle, 2017; Dover, 2013; Brown, 2017). It is a pedagogical approach based on academic success, cultural competence, and sociopolitical consciousness and builds classroom instruction that is both culturally informed and asset based (Figure 2; Barron et al., 2021). According to Ladson-Billings (1995), academic success refers to the intellectual growth that students experience as a result of classroom instruction and learning experiences; cultural competence means helping students to recognize and honor their own cultural beliefs and practices while acquiring access to the wider culture; and sociopolitical consciousness is the ability to take learning beyond the confines of the classroom using school knowledge and skills to identify, analyze, and solve real-world problems. At its core, CRST seeks to

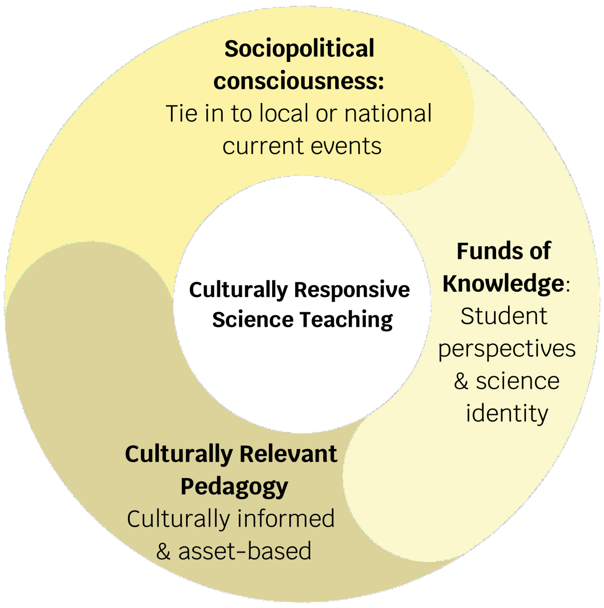

FIGURE 2
Three components of the culturally responsive science teaching framework adapted from Barron et al. (2021).

create positive science identities and experiences—making science self-relevant, especially so students who have been historically excluded from the sciences feel like they have a rightful presence in the classroom. Generally, culturally responsive instructors are acutely aware of their students' needs in the classroom and strive to make appropriate adaptions when necessary (Brown and Crippen, 2017; Barron et al., 2021; Brown and Crippen, 2016). Culturally responsive science teaching may be used to mitigate the effects of sociostructural disparities and systemic oppression on historically marginalized students in science classrooms (Barron et al., 2021). Specifically, culturally responsive science teaching and other culturally-centered pedagogies have been linked with improved student outcomes including student empowerment, self-efficacy, and ethnic and academic identity (Aronson and Laughter, 2016).

3 Purpose statement and research questions

Although CRST and other culturally-centered pedagogies have been broadly studied in K-12 educational spaces and sparsely studied in undergraduate college science spaces (Barron et al., 2021), more research assessing whether graduate TAs in college science are familiar and prepared to engaged in CRST is needed. Therefore, the purpose of our exploratory study was to assess the extent to which graduate teaching assistants in college science reported using IST and CRST in their classrooms, and whether they experienced any barriers to doing so. Our research questions were as follows:

- How do graduate teaching assistants describe using IST and CRST before and after receiving relevant training?
- How do graduate teaching assistants describe their barriers regarding IST and CRST before and after receiving relevant training?

4 Positionality statements

Inspired by work done by Boveda and Annamma (2023), we have written this positionality statement as a group. We are six scholars who self-identify as a descendent of the White Earth Band of Ojibwe (Hillary), White Hispanic (Isabella and Erik), and White Non-Hispanic (Kaylyn, Laura, and Petra). Most self-identify as cisgender, heterosexual women, but one self-identifies as a cisgender, heterosexual man (Erik). Most do not self-identify as having a disability, but one does (Petra). Two of us were first generation college students (Hillary and Isabella), while others were continuing education college students (Kaylyn, Laura, Erik, and Petra). We have all been working at Minority-Serving Institutions as either an undergraduate student (Isabella), a graduate student (Kaylyn), or tenure-track faculty (Hillary, Laura, Erik, and Petra). As a result of our social identities and positions, we have each experienced power and marginalization during our research, teaching, and mentoring efforts in the natural sciences, and because of these experiences we are all motivated to do STEM education research focused on investigating the unique life experiences and assets that our graduate students bring to life sciences education at the University of California Merced (UC Merced). UC Merced is a Hispanic-Serving Institution (HSI) and Asian American and Native American Pacific Islander-Serving Institution (AANAPISI). Hillary's graduate and postdoctoral research focused on creating equitable and culturally responsive science learning opportunities for students at a very high research activity (R1), Primarily White Institution (PWI). Hillary has previously published on CRST and has developed many teaching professional development opportunities for faculty and students. Therefore, when Hillary and Petra started their faculty positions at MSIs in 2019, they wanted to expand Hillary's culturally responsive science teaching training with graduate teaching assistants beyond the R1 PWI space.

5 Methods

The studies involving human participants were reviewed and approved by the Human Subjects Committee of the UC Merced Institutional Review Board (IRB; Protocol ID 2020-3). The participants provided their informed consent to participate in this study.

5.1 Institutional context

UC Merced is a mid-sized, public, research-intensive university in the University of California system. It is designated as a Minority-Serving Institution (MSI), included as both a Hispanic-Serving Institution (HSI) and Asian American and Native American Pacific Islander-Serving Institution (AANAPISI), under the guidelines of the US Department of Education. During the time of this study (Fall 2020 semester), all courses were taught remotely.

The undergraduate population in the life sciences at UC Merced was primarily California residents (99.4%), with a majority identifying as heterosexual or straight (88%), first-generation (72%), female (68%), and Pell-Grant eligible (64%). The racial demographics were as follows: 52.2% Hispanic/Latino(a), 23.3% Asian, 9.0% White, 6.8% African American/Black, 6.3% International, 1.6% Domestic unknown, 0.5% American Indian, and 0.2% Pacific Islander (University of California, 2020).

The graduate population in the life sciences at UC Merced was primarily California residents (72.0%), with a majority identifying as heterosexual or straight (68%) and female (50.5%). The racial demographics were as follows: 26.9% White, 24.2% International, 21.5% Hispanic/Latino(a), 12.9% Asian, 11.8% Domestic Unknown, 2.2% African American, and 0.5% Pacific Islander (University of California, 2020).

5.2 Course design and curriculum

The course in this study was offered virtually during emergency remote teaching (ERT) in Fall 2020. It met once a week for 16 weeks, with each class session lasting 110 min. The course was designed by instructor and researcher PK to support graduate students in the sciences who are interested in improving their students' learning and pursuing a career in college science teaching.

The course design and curriculum were based on the pedagogical framework Scientific Teaching (ST; Handelsman et al., 2007; Pfund et al., 2009). In advance of designing this course, researchers and instructors PK and HB participated in the Summer Institute on Scientific Teaching (Pfund et al., 2009) and have experience facilitating both faculty and graduate teaching professional development. A copy of the course overview, learning goals, learning outcomes, and weekly course schedule can be found in Supplementary material.

5.2.1 Training sessions

For this study, graduate TAs from UC Merced engaged in training for IST and CRST and were challenged to reflect on and implement those strategies in their lectures, discussions, and/or lab sections. During two class sessions in the professional development course, described above, students participated in targeted trainings led by instructor and researcher HB that focused on IST and CRST. PK and HB designed each session to provide contextual background and theoretical information for students, while also supporting their development through prompted discussions and brainstorming activities. We have outlined the details of the two class (or training) sessions below. Also, see Figure 3 and Appendix A for timing of the two sessions in the context of the entire course.

5.2.1.1 Session 1: inclusive, equitable, and culturally responsive science teaching

Before the first session, PK assigned a written teaching reflection based on two reading assignments (Tanner, 2013; Brown and Crippen, 2017) and the students were asked to reflect on the assigned articles. See Table 1 for question prompts. During the first session, HB introduced students to broad ideas of inclusivity and equity using the three domains of the ST framework: Inclusive Teaching, Active Learning, and Assessment (Handelsman et al., 2007). The ST framework calls attention to the importance of inclusion in STEM learning, which HB utilized as a foregrounding concept to then introduce students to CRST. Then, HB asked students to do a quick write on their own with the following two questions prompts: (1) "Why else is inclusive teaching important in undergraduate science classes?" and (2) "Why is inclusive teaching important to you?" Next, participants were split into three virtual breakout rooms, and were tasked with brainstorming how they would apply several of Tanner (2013) strategies for equitable active learning. Each group was assigned one or more strategies (e.g., "multiple hands, multiple voices," "hot potato or amplification," etc.) and instructed to identify a particular topic and then plan how they would use their strategy during instruction of that topic. Breakout groups then reconvened with the larger group and shared their ideas. Lastly, HB connected social justice and cultural responsiveness to inclusive teaching. This discussion highlighted both a theoretical overview of CRST as well as practical applications that educators could use in classrooms and laboratories. Students once again entered the same virtual breakout rooms and responded to these prompts: (1) What personal experiences or reactions are coming up for you and equity-focused science education? (2) What knowledge and perspectives do you bring to this work? and (3) How can you incorporate these perspectives on equity into your teaching?

After the first session, PK assigned another written teaching reflection with the same question prompts as before class. Students were prompted to either state that their answers remained the same or asked to elaborate on how their ideas might have changed. See Table 1 for more details.

5.2.1.2 Session 2: digging deeper in culturally responsive science teaching

The second session took place 4 weeks after the first one. Before the second session, PK assigned a written teaching reflection based on two reading assignments (Brown and Crippen, 2017; Upadhyay, 2006) and the students were asked to reflect on the assigned articles. See Table 1 for question prompts. Session two focused on three domains of CRST: culturally relevant pedagogy, funds of knowledge, and sociopolitical consciousness (Figure 2; Barron et al., 2021). First, HB started with an overview about how all science is cultural and asked the students to write about "In what ways have you observed science as cultural or science learning as cultural?" Then, she reviewed the three domains of CRST before asking students to engage in targeted brainstorming in virtual breakout sessions. There, students were tasked with discussing and potentially developing instructional approaches that incorporated one or more of the CRST domains. Next, students completed a virtual "gallery walk" to view and discuss each other's strategies during which, HB shared each group's planning document, allowed 2–3 min for the whole group to review, and then invited each group to describe their ideas for incorporating CRST into their teaching.

After the second session, PK assigned another written reflection with the same question prompts as before class. Students were prompted to either state that their answers remained the same or

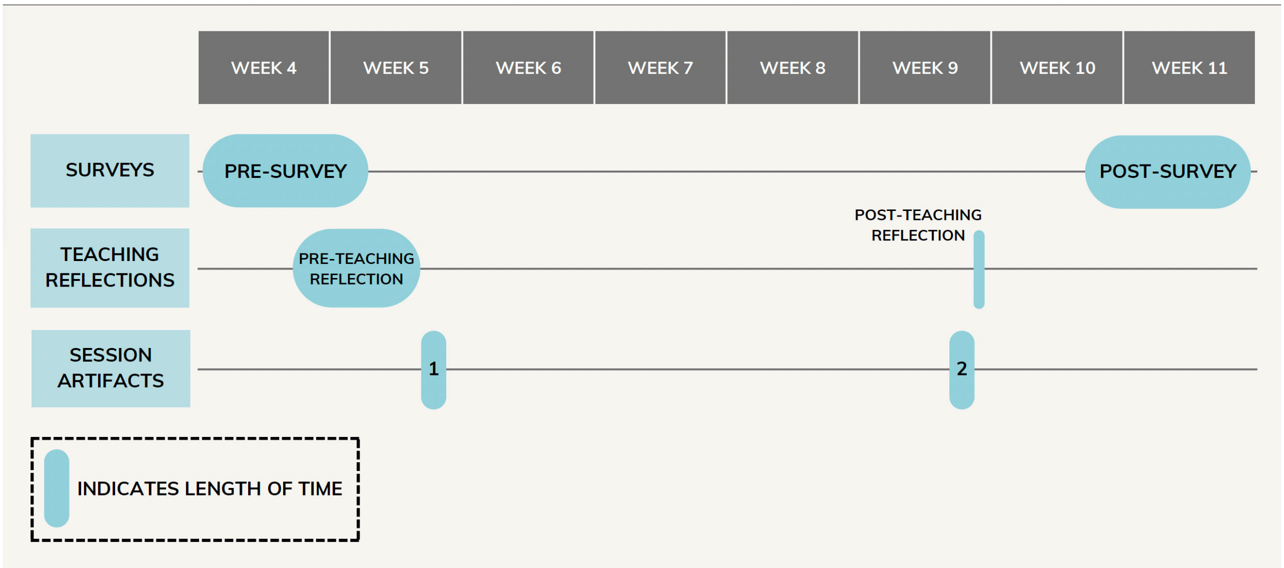

FIGURE 3
Timeline of data collection for three data sources throughout the teaching professional development course. The numbers 1 and 2 indicate when the training session occurred.

TABLE 1 Overview of lesson plans for two training sessions of inclusive science teaching and culturally responsive science teaching.

	Session 1	Session 2
Written reflections	• What is your understanding of the difference between inclusive and equitable teaching? • How do you envision being equitable in your teaching? • Please briefly describe your current knowledge of social justice and, if applicable, provide examples in which you have used social justice in your science classroom or education.	• How does culturally responsive science teaching promote equity? • What is an example of culturally responsive science teaching? • Define funds of knowledge.
Mini-lecture topics	• Intro to Scientific Teaching Framework • Structural inequities in science teaching	• Connections between social justice, cultural responsiveness, and inclusive teaching • CRST model of culturally responsive pedagogy, funds of knowledge, and sociopolitical consciousness
Peer discussion prompts	• How can you apply different strategies for equitable active learning? • What personal experiences or reactions are coming up for you and equity-focused science education? • What knowledge and perspectives do you bring to this work? • How can you incorporate these perspectives on equity into your teaching?	• What personal experiences or reactions are coming up for you and equity-focused science education? • What knowledge and perspectives do you bring to this work? • How can you incorporate these perspectives on equity into your teaching?

asked to elaborate on how their ideas might have changed. See Table 1 for more details.

5.3 Data collection

5.3.1 Participants

Researcher EM recruited participants from a semester-long graduate level teaching professional development course taught by instructor PK at the UC Merced after the course was completed. Five out of the nine students in the course agreed to participate in the study. All five participants were graduate students in the life sciences that had served as a graduate teaching assistant for discussion and/or lab sections for at least 1 year at UC Merced. Additionally, all participants had attended at least one seminar or workshop focused on teaching or education prior to enrolling in this course. We did not collect individual demographic information. Researcher KM created gender and ethnically appropriate pseudonyms to de-identify them and retain their privacy and confidentiality.

5.3.2 Surveys

Students completed surveys 2 days before the first class session (i.e., pre-survey) and 2 weeks after the second class session (i.e., post-survey; Figure 3). Students were given points as part of the course for completion of these surveys. Researchers HB and PK adapted questions from the teaching assistant professional development program at the University of Minnesota called "Building Excellence in Scientific Teaching (BEST;

Patrick et al., 2021).” The survey questions can be found in Supplementary material.

5.3.3 Triangulation

5.3.3.1 Teaching reflections

In addition to the surveys, students also completed teaching reflections written by researchers HB and PK before (pre-teaching reflection) and after (post-teaching reflection) the class sessions (Figure 3). Teaching reflection prompts encouraged students to reflect on material taught in the professional development course and related to class session content as well. These responses were open-ended and based on reading assignments.

5.3.3.2 Session artifacts

For a third data source, we collected two sets of session artifacts (Figure 3). More specifically, we recorded and later transcribed the two sessions from Zoom to holistically capture the range of activities and discussions during each training session. Discussions that took place using the chat feature of the virtual platform were exported and saved. Lastly, all brainstorming documents that the participants utilized during each training session were exported from the shared document space and saved. See Figure 3 for a timeline of the data collection for the three data sources.

5.4 Data analyses

5.4.1 Surveys

Researchers KM and IW used a combination of first- and second-cycle qualitative coding methods (Saldaña, 2015), deriving codes and categories directly from the data. This iterative approach allows for systematic, methodological coding that leads to the development of categories grounded in the data (Corbin and Strauss, 2014; Creswell and Creswell, 2018).

5.4.1.1 Qualitative inductive coding—first cycle

First, researchers KM and IW used open coding, an inductive coding process where researchers develop an integrated perspective of the data by identifying discrete aspects of the data (Saldaña, 2015), on responses from five respondents and for each of the four research questions. Additionally, KM and IW utilized analytic memos, which serve as a record of notes and lines of questions during the coding process to clarify codes and make further decisions about categories (Charmaz, 2006; Corbin and Strauss, 2014). Next, IW and KM met for first-cycle consensus coding to ensure validity across codes, as multiple perspectives are clarified and discussed (Miles et al., 2019; Charmaz, 2006). As part of this process, they discussed these codes, their corresponding analytic memos, and created convergent codes as needed.

5.4.1.2 Qualitative inductive coding—second cycle

Second-cycle qualitative coding methods allow researchers to identify links between open codes and to develop categories that clarify overarching messages in the codes (Saldaña, 2015). Specifically, we used pattern coding to attribute meaning to similarly coded data and group them into a smaller number of categories (Miles et al., 2019; Saldaña, 2015). First, IW and KM individually completed pattern coding by sorting the agreed upon codes from the first-cycle consensus coding into patterns codes or categories. Next, IW and KM met for second-cycle consensus coding to compare and refine the pattern codes or categories.

5.4.2 Teaching reflections

5.4.2.1 Qualitative deductive coding

Researchers LBJ and EM individually deductively coded the teaching reflections using the categories established in second-cycle coding of the survey data. Deductive coding describes a coding process where researchers use previously established codes and categories to analyze a data source (Saldaña, 2015). LBJ and EM utilized analytic memos to serve as a means to justify thoughts, opinions, or clarifying statements when coding (Charmaz, 2006; Corbin and Strauss, 2014). Next, LBJ and EM met for consensus coding to ensure validity across their individually-coded segments, to ensure each of their perspectives were cogent and discussed (Miles et al., 2019; Charmaz, 2006). As part of this process, they discussed data identified through the coding process, corresponding analytic memos, and resolved differences as needed.

5.4.3 Session artifacts

Session artifacts included transcripts from training sessions and excerpts from shared brainstorming documents utilized by participants during training in the class sessions. Researcher HB used the session artifacts primarily as a triangulation data sources, employing deductive thematic analysis to look for key similarities between the artifacts and other data sources (Charmaz, 2006; Corbin and Strauss, 2014). After compiling common themes, HB presented the triangulated findings to the rest of the research team. The team collectively engaged in a consensus-building discussion to identify how the themes fit into the overall findings.

5.5 Reliability and validity

Reliability in qualitative research refers to the consistency in research methods and interpretations between researchers on the same project (Creswell and Creswell, 2018). To ensure reliability throughout the survey coding process, KM and IW reviewed open-ended responses to ensure there were not any obvious mistakes or misinterpretations of the answers provided by the respondents. After each coding consensus meeting, KM and IW presented the data and consensus codes and patterns to the other four researchers on the research team. This process of peer debriefing allowed for feedback and discussion to ensure reliability and trustworthiness in the qualitative results, with the goal of minimizing researcher bias. Feedback provided by the research team allowed for inter-coder agreement and steered the coding process in the appropriate direction. The team also ensured qualitative reliability by consistently reviewing and refining code definitions through discussion and analytic memos. During each round of coding, each researcher provided analytic memos to justify and explain their thought processes while creating codes and patterns. These memos were referenced during consensus meetings and provided evidence for researcher’s reasoning while coding. KM and IW discussed code definitions thoroughly in each consensus meeting, clarified their interpretations of the definitions, and used analytic memos to clarify or support their coding definitions throughout the process.

Validity, or trustworthiness, refers to the accuracy of the findings in qualitative research (Creswell and Creswell, 2018; Merriam and Tisdell, 2015). The researchers established trustworthiness through the process of triangulation. Triangulation can be achieved in different ways, such as the use of multiple data sources, multiple data collection processed, multiple investigators, and/or use multiple theories (Merriam and Tisdell, 2015). Triangulation of the data allowed us to understand how the data converged and led us to build a reasonable justification for the categories and themes which arose from analysis (Creswell and Creswell, 2018).

In our study, the survey data were coded originally, and then the teaching reflection data was coded using the categories derived from the surveys. Finally, these two data sources were triangulated with the session artifacts. Each key piece of data (surveys, teaching reflections, and session artifacts) were overseen by different investigators to increase trustworthiness and methodological rigor. Lastly, guided by the principles we utilized to achieve consensus in coding (Charmaz, 2006; Miles et al., 2019), we engaged in a process of discussion-based consensus for triangulation. We held several meetings to clarify and discuss potential differences across the team in our conclusions about the triangulated data sources, addressing our multiple perspectives, until we reached agreement.

Each researcher provided a positionality statement (see above) to clarify any biases they may bring to the data analysis process. Although positionality statements do not remove bias from the results, they aim to help readers understand the perspectives through which the results were determined.

6 Results

The results are presented by research question, where we explored how graduate TAs described using IST and CRST before and after relevant training (RQ1). Then, we examined how graduate TAs described barriers to using IST and CRST (RQ2). Within each research question, we presented each set of findings before and after relevant training. Research questions are answered with exemplar categories and quotes that are both shown in italics; however, the full codebooks can be found in Supplementary Tables C1–C4.

6.1 Use of IST and CRST

6.1.1 Before training

One way graduate TAs reported using IST and CRST was by *building connections through student information*, which involved graduate TAs trying to understand students as individuals and learning about them. For example, Solaris said:

> *"I try to learn all the students' names and pronouns by using some kind of icebreaker and name card activity at the start of the semester. I typically use index cards that I have them fill out with their name, nickname, preferred pronouns, their major, and an interesting fact about themselves."—Solaris*

This quote displays how Solaris made an intentional effort to get to know the students by collecting specific information about them via index cards at the onset of the semester. Notably, Solaris went beyond learning just student names by also asking for their pronouns and an interesting fact about them. Solaris described engaging in these behaviors prior to receiving the class trainings, indicating that trying to learn about their students was already a priority for them.

Another way that graduate TAs described using IST and CRST was discovered during an individual quick write in the first training session. Graduate TAs, like Lizzie, described how they were using *intentional teaching strategies*, including facilitating student interaction and providing individualized attention to all students, while responding to the question prompt, "Why is inclusive teaching important in undergraduate science classes, and why is it important to you?":

> *Lizzie: (1) Important to make people feel included which also boosts confidence of typically shy students classroom setting. (2) Inclusive teaching is important to me because I want to make sure my students feel supported.*

Lizzie described the importance of tailoring her teaching practices to the needs of the particular students that she has in the classroom, including considering strategies that might boost confidence and support shy students. This awareness of the types of students in her classroom leading to adjustments in her teaching is an example of how she was already using elements of IST and CRST.

Another commonly used technique described by graduate TAs, and also described by Lizzie, included *facilitating emotional comfort in the classroom*. Lizzie described how she tries to be compassionate toward her students and reduce student anxiety by normalizing failure as part of the process:

> *"So when I don't know something I directly say 'I have no idea, let's look it up" and I think that eases pressure off of them thinking that they should know it."—Lizzie*

This quote describes how Lizzie was intentional in acting in a way that may specifically reduce anxiety for their students if they are confused. Lizzie described how she made a direct effort to prioritize students' *emotional comfort in the classroom*.

This idea was also mirrored in the written teaching reflections on a question focused on describing their use of social justice in science classrooms, where Noah grapples with balancing their knowledge of social justice with *facilitating emotional comfort in the classroom*:

> *"I try not to project my views on students or say too much because I know I can be too intense on these topics and not everyone shares my views and I want students to feel comfortable sharing their thoughts, but it's hard for me to find a balance there."—Noah*

Noah described trying to grapple with wanting to share their views of various social justice topics as it relates to the science teaching but still wanting to make sure all of the students in their classroom feel comfortable.

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In the survey, Noah also reported *engaging in sociopolitical consciousness* as a way to enact inclusive teaching:

> *"[I try to] include information about historically disenfranchised people's contributions to whatever STEM topic I'm covering."—Noah*

Noah's quote specifically named "historically disenfranchised people" prior to the class sessions. This is an important signifier that some graduate TAs, like Noah, were already reflecting on the ideas of sociopolitical consciousness before receiving the training.

This idea was also supported in the teaching reflections that asked the graduate TAs about how they envisioned being equitable in their teaching. Solaris' response supported an active effort to engage in *sociopolitical consciousness* as a means to achieve equity:

> *"I would work to identify where racial, cultural, and gender social biases might intersect with what I am teaching and try to counteract that influence."—Solaris*

While the concept of *sociopolitical consciousness* was reiterated during the class sessions, this quote demonstrates how some graduate student TAs, like Solaris, were already intentionally trying to provide representation and highlight contributions from diverse scientists when teaching. This is one aspect of *sociopolitical consciousness*, which describes techniques used to connect material to the reality outside of the classroom.

This was also reinforced when the graduate TAs discussed the importance of intentionally using strategies, like *sociopolitical consciousness*, as a way to address structural inequities in undergraduate science education. Specifically, they reacted to and discussed the prompt, "What are inequities in science learning, and why do you think they exist?" For example, Matteo said:

> *"It could be due [to] the difference of opportunities since basic education (resources, interest from teachers in students' progress, financial aid) that snowballs into higher education."*

Matteo was explicitly describing systemic inequities in our educational system that starts in primary and secondary education and continues into higher education. The results we have highlighted illuminated the varied ways in which graduate TAs used IST and CRST on their first stop of their journey along teaching professional development. These results also exhibit the ways graduate TAs started to discuss and center equity as a goal of CRST.

6.1.2 After training

After our training sessions, we found that graduate TAs were still *building connections through student information* not only by learning their preferred names and pronouns, but also through soliciting their feedback:

> *"I also usually do a mid-semester survey check with them to incorporate their suggestions or make necessary changes."—Noah*

Noah's response indicates that they are practicing inclusivity by prioritizing the voices of students in their classroom. Creating a mid-semester survey was an intentional effort by Noah to not only seek student feedback, but also to apply the suggestions from the feedback into their teaching. Similarly, the post-session teaching reflections included examples of ways the graduate TAs were *building connections through student information* in their classrooms. For example, Kendall said:

> *"I would really like to incorporate students' previous cultural experiences with course content. It will be a great way to engage them and also learn a lot about them."—Kendall*

Kendall's response is an example of how she described using IST and CRST by engaging students in conversation about the intersections between course content and cultural experiences.

There was also a repeated perceived effort to *facilitate emotional comfort in the classroom* through actively attempting to reduce student anxiety with Kendall stating that:

> *"I try to be welcoming in the vocabulary I use and frame a way that does not put down answers." —Kendall*

Kendall's quote is an example of how graduate TAs, like her, prioritized student comfort and used welcoming language as a means to facilitate that comfort. This intentional choice to use wording that would not discourage or embarrass students for having potentially incorrect answers demonstrates attention to inclusivity. Kendall moved beyond simply learning student information and made a concerted effort to provide opportunities for success within the classroom.

In addition, graduate teaching assistants used *intentional teaching strategies* after both class sessions. Specifically, graduate TAs referenced particular teaching strategies they implemented in the classroom:

> *"I have used TPS and other active learning practices in my teaching."—Solaris*

Here, Solaris discusses using *intentional teaching practices*, including Think-Pair-Share (TPS), a specific teaching strategy aimed at engaging with students through reflection and peer and group discussions. This response from Solaris indicates that some graduate TAs may be utilizing these intentional teaching strategies in an attempt to bring inclusivity and cultural responsiveness to the classroom, perhaps through giving students' opportunities to share their own experiences through discussion.

In the second training session, the graduate TAs also discussed that interrogating the concept of success was also an important aspect of inclusive and culturally responsive teaching for them. This idea of *achieving equality* was made clear in the following report out from a breakout room group discussion:

> *So our question was: are there multiple ways for students to achieve success? And first of all, we defined what success is, identify ways of success, set goals. Define success for the students but also define what would the teacher define as success. So there*

> *are two levels of success. And an objective way to define success would be to understand what you learn in class and furthermore to apply later on what you learn into a higher level. And we kind of discuss what would be evolutionary success. We think in the animal kingdom success in evolution would be having the most offsprings as possible. But for humans, we have another understanding of success. We want to have a good job, a good career, which at the end of the day would be a means to an end to an evolutionary success. But that's a way to explain how success could be circumstantial sometimes.*

The graduate TAs in this breakout room group discussion were trying to make sense of how to achieve equality in classrooms by using an analogy about evolutionary success. They were describing how humans may be part of the animal kingdom, but the definition and concept of success varies when using an evolutionary vs. social lens.

Lastly, after the class sessions, graduate TAs were *promoting growth mindset* as a means of using IST and CRST in their instruction. Growth mindset was taught during the class sessions and did not appear in responses prior to the training, signaling that either this concept in its entirety was learned about in the class sessions, or that language regarding this concept may have been acquired in the trainings; for example:

> *"[I] encourage a growth mindset."—Matteo*
>
> *"I have been trying the growth mindset techniques we recently learned about."—Kendall*

The graduate TAs' specific recall of *promoting growth mindset* demonstrates efficacy in the class sessions, as this language was emphasized in training sessions.

6.2 Barriers to teaching strategies

6.2.1 Before training

One significant barrier mentioned by graduate TAs on their first stop in their journey of teaching professional development was *lack of structural resources*, which was repeated throughout graduate TAs' responses. This emerged in various ways as graduate TAs perceived a general lack of structural and normative support for CRST:

> *"I think traditions in teaching and expectations might be a barrier to culturally responsive teaching." —Solaris*

Similar responses came up in Noah's teaching reflections:

> *"I really would like to move beyond the examples I gave [earlier], but find it challenging especially when teaching science classes that have traditionally (sic) been 'apolitical'"—Noah*

These responses specifically identified the traditional norms in science teaching to be contentious with CRST, indicating that implementing CRST would upset the norms or expectations systematically put into place. Solaris and Noah touched on a prominent issue in college science teaching: despite advances in active learning and inclusive teaching, dismantling structural barriers in science learning remains challenging for instructors (and graduate TAs) in STEM classrooms.

The graduate TAs also perceived a *lack of training* as a barrier:

> *"Not having sufficient training feels like the biggest [barrier] at my level."—Noah*

Because culturally responsive science teaching and inclusive teaching practices are not implemented at a systemic level, a real or perceived lack of training may prohibit graduate TAs from engaging in such techniques. For example, Noah felt that a lack of training from the university or their graduate program inhibited their ability to engage in culturally responsive science teaching successfully. This quote may also indicate that graduate TAs may be hesitant to engage in inclusive practices or culturally responsive science teaching if they feel they do not have the knowledge to do it well.

Graduate TAs also perceived a general *resistance* at the classroom level and within university-culture to engaging in inclusive teaching practices and culturally responsive science teaching. They reported feeling a sense of close-mindedness regarding assessment or evaluation from external sources, including administrators or public opinion, if they were to engage in these teaching practices:

> *"I think there is still a lot that needs to be done to change the accepted ideas on assessment."—Kendall*

Kendall's response suggests that even if they were to change their teaching methods, they would expect resistance. For example, high-stakes exams that foster rote memorization are still widely promoted and accepted as assessment of student learning in higher education STEM courses. Kendall's response signifies that overcoming student or administrator perspectives of assessment may take substantial effort.

The *resistance* was also perceived as a cultural issue:

> *"You may get resistance to being inclusive of non-Western narratives."—Noah*

This response refers to historical and systemic resistance to inclusion of historically and currently excluded groups, as well as inclusion of culture-based conversations in STEM education. A non-Western narrative, for example, could mean incorporating broader diversity of representation of scientists to combat the over-representation of White, heterosexual, cisgender men.

Graduate teaching assistants also perceived their own *instructor implicit biases* as barriers to inclusive teaching practices and culturally responsive science teaching prior to the first class session. A concern for personal implicit bias was reported by Lizzie:

> *"If you are from your own culture/background then you have a certain way of teaching/perspective and that is a barrier in itself."—Lizzie*

This graduate teaching assistant acknowledged that they need to overcome, or at least be aware of, their own implicit biases that arise from individual experience in order to best engage in inclusive teaching practices.

The results prior to the trainings suggest that graduate teaching assistants perceive general barriers in the academic system including resistance and a lack of training, while also perceiving their own biases as barriers.

6.2.2 After training

After learning about how to enact IST and CRST, the most commonly reported barrier was a *lack of time* or opportunity to enact these techniques:

> *"Not having enough time with students to build trust and incorporate inclusive practices [is a barrier]."—Noah*

This response demonstrates that graduate TAs feel time is a constraining factor in implementing inclusive teaching practices, and therefore, they may be less likely to try to use them. Noah also echoed this sentiment in their post-training teaching reflections:

> *"A lot of this stuff seems easier to implement at younger levels where teachers are spending far more time with students."—Noah*

The graduate TAs aspire to incorporate skills taught in the class sessions while also communicating that a lack of time feels like an insurmountable barrier to enacting these teaching strategies.

Another barrier noted by graduate TAs was perceived difficulty in *achieving equality* in their classrooms. This was especially interesting, as class training sessions were focused on teaching about the importance of equity and social justice, not equality. Despite this, Lizzie reported difficulty in *achieving equality:*

> *"I think barriers to using inclusive teaching practices would be to know how to include a group of students based on cultural differences but also making sure other groups don't feel excluded at times. It's good to make sure everyone has a chance of feeling connected but I think a challenge is to know how well you're dividing up that attention and how effective you are at actually making student group feel included."—Lizzie*

As well as, in teaching reflections, Matteo said:

> *"[T]o have a class with cultural background so diverse that I can't effectively use responsive science teaching techniques."—Matteo*

Within Matteo's response, he expresses care and desire for inclusivity and equality, but conveys intimidation that they might not succeed, or may inadvertently exclude students who are not actively prioritized as being included. This barrier is unique and was not reported prior to the class trainings, suggesting that graduate teaching assistants identified new barriers to using inclusive teaching practices and culturally responsive science teaching after receiving the training.

The limited time perceived by the graduate teaching assistants was similar to another perceived barrier of *increased effort enacting* the culturally responsive methods. Some graduate teaching assistants expressed desire to incorporate inclusive teaching methods into their classes, but acknowledged the potential burden of changing their classrooms:

> *"Because the field is still generally not centered on CRST practices, it might mean more building classes from scratch rather than relying on other templates, which may be difficult for new teachers."—Noah*

This response indicates that structural change may be difficult to implement on an individual level, but that enactment may become easier as greater systematic changes are realized.

7 Discussion

Graduate TAs in college science are positioned to have substantial and direct contact with undergraduate students, giving them many opportunities to promote equity and justice in STEM education by using asset-based teaching strategies. To do so effectively, it is important that they participate in pedagogical training, such as being exposed to the CRST framework, to help address structural inequities in STEM education (Barron et al., 2021). Previous work has focused on how undergraduate TAs at a very high research activity (R1), Primarily White Institution (PWI) enacted (or did not enact) CRST with ease or difficulty (Barron et al., 2021); however, we wanted to conduct an exploratory study examining training of graduate TAs in a different setting. Particular, we conducted our study at a high research-intensive (R2) that is also designated as a MSI. The purpose of our study was to assess how graduate TAs in college science described implementation and barriers to IST and CRST in their classrooms. In the subsequent sections, we will outline the main takeaways, limitations and future directions, and recommendations for developing graduate teaching professional development programs focused on CRST.

7.1 Main takeaways

Our findings suggest that graduate TAs serving undergraduate STEM courses at an MSI were aware of structural inequities before receiving training on IST and CRST. In particular, TAs' responses indicated their awareness that their students entered the classroom with different life experiences and were intentional in acknowledging these differences. This indicates that the TAs were already thinking and acting in inclusive manners in their classes by understanding their students' different lived experiences. In addition to understanding the diverse experiences of their students, graduate TAs also engaged in sociopolitical consciousness prior to receiving training. Specifically, graduate TAs reported awareness of their own individual biases, efforts to provide representation of minoritized identities in the classroom and attempts to connect the classroom material with global and personal events. Some of the graduate TAs were already engaging and reported efforts to make connections with their students by learning their names, pronouns, backgrounds, and professional goals. Also, they described attempting to facilitate emotional comfort within their classrooms by creating welcoming environments where students did not need to be afraid of failure or getting an answer wrong. All of these strategies are key recommendations from the CRST framework (Barron et al., 2021), and indicate that the specific sample of graduate TAs at this MSI may have already been enacting culturally responsive techniques prior to receiving training. One reason for this might be that graduate TAs who consented to the study were already enrolled in a teaching professional development course, so they may be more likely to care about being a successful teaching assistant than other TAs who did not enroll in the course (Lüke and Grosche, 2018). This may be important for researchers or universities developing professional development for TAs to understand, as TAs may enter the professional development space with different lived experiences, goals, or backgrounds (Green, 2010). It may also be relevant to highlight the ways in which graduate teaching assistants are *already* acting in inclusive and culturally responsive ways, as this awareness may promote self-efficacy for utilizing IST or CRST in the future (Embry, 2006; Prieto and Altmaier, 1994; Dewsbury, 2019; Barron et al., 2021).

After the graduate TAs participated in the IST and CRST trainings, they described several noteworthy practices and barriers as they progressed along their learning journey. Of importance, the TAs described using new language to explain their teaching and interactions with students. For example, prior to participating in the training, the TAs would describe philosophies consistent with having a growth mindset but did not use this term until after participating in the class trainings. Interestingly, despite the emphasis in the training on differentiating between equity and equality, and the focus on providing an equitable environment in the classroom, the TAs consistently used the term "equality" after the training, even when describing equity (Espinoza, 2007; Madkins et al., 2020; Van Dusen and Nissen, 2020). The confusion between equity and equality, however, is not uncommon and reflects different groups using these terms for different things, and because the TAs where consistently describing what we think of as equity, we are less concerned about the terminology and instead focused on the outcomes. Finally, TAs frequently reported a lack of structural resources and time as perceived barriers to engaging in IST and CRST. This likely indicates that the TAs found these teaching practices difficult to enact quickly without practice. As suggest by Ladson-Billings (2021), novice teachers have been shown to struggle with implementation of the theory in their own practice.

Our findings describe IST and CRST learning as a journey for the graduate TAs in our study. We found changes in their perspectives over the course of several weeks, but we did not measure the effects of the class trainings in a quantitative manner because we contend that the nature of being an inclusive and culturally responsive instructor is a learning journey, not a static measure. Similar to the ideas presented in Addy et al. (2023), we hope that graduate TAs, like those in our study, continue to take responsibility for making their teaching and curriculum inclusive, continue to learn about their students and how to teach them, care about and for each and every student they teach, and change their teaching based on evidence about the practices that support and challenge all students to thrive.

7.2 Limitations and future directions

We believe that we have provided strong evidence and clear interpretations of these data; however, there are still limitations that are important to consider and opportunities for future studies in other contexts. As a study qualitative in nature, the stories from our five graduate TAs are powerful for understanding the strengths and challenges that graduate TAs face in equitable and socially just STEM education. Our sample was intentionally small and targeted toward a specific study context, so our results are not generalizable nor representative of graduate TAs at MSIs. Additionally, our IST and CRST trainings were adapted based on our extensive experiences implementing them in-person at a R1 PWI, but for this study, we implemented the trainings virtually during the COVID-19 pandemic. Therefore, we would like to implement the trainings again in-person, fully remote (combination of synchronous and asynchronous), and/or hybrid. Other STEM educators and researchers should examine the impacts of graduate teaching professional development, especially those workshops, trainings, and courses focused on diversity, equity, inclusion, and social justice, in their own unique context via various instructional modalities as findings may differ from those found in this study. Also, we suggest that these research teams consist of members with different lived experiences, backgrounds, and perspectives, including students, staff, and faculty in the process.

Also, our study has focused on perceived uses and barriers, but not observed uses and barriers to teaching using the theories of IST and CRST. Therefore, similar to the lab observations of each undergraduate TA's instruction conducted in Barron et al. (2021), future studies should focus on documenting the variety of ways that graduate TAs enact CRST. Similar to Barron et al. (2021), it could be interesting to conduct interviews after the lab observations to document both what processes of CRST were occurring as they were teaching as well as what their perceptions were of their enactments of CRST.

Finally, while graduate TAs can have a profound impact on STEM education through the way that they teach and mentor students in discussions and labs (Hicks et al., 2022; Philipp et al., 2016), instructors of record are the main drivers of the culture, climate, and curriculum of their courses. Therefore, we suggest that these IST and CRST trainings are expanded to instructors, especially faculty in higher education. Previous studies have called out this need for professional development opportunities that support faculty members in embracing diversity as an asset and becoming more culturally responsive in their teaching (O'Leary et al., 2020; Dewsbury, 2017).

7.3 Recommendations for developing graduate and faculty teaching professional development programs focused on CRST

7.3.1 Use a culturally responsive approach to professional development and incorporate varied voices

Our study showed that graduate students at this particular MSI already came into the course with a foundational knowledge of sociostructural disparities, and an awareness that students in STEM courses should be able to draw on their lived experiences in their STEM learning. This is not always the case. Effective professional development of graduate teaching assistants, as well as faculty, requires that we meet instructors where they are, just as we would in utilizing CRST in undergraduate STEM teaching. For example, we should structure professional development in ways that validate the participants' cultural identities (culturally responsive pedagogy), gather information about and privilege lived experiences and prior knowledges (funds of knowledge), and be intentional about local and regional social justice science issues that relate specifically to that group of participants (sociopolitical consciousness).

7.3.2 Develop sustained, reflexive opportunities for growth

Our findings showed that graduate students approached teaching as a pathway to improve their pedagogy, and not merely a checklist of things to do in the classroom. Graduate students recognized that it is an ongoing process of personal and professional growth. We need to provide all STEM instructors with long-term support in CRST that extends beyond a series of workshops or a semester. Recognizing that there are systemic barriers to this particular recommendation, a key starting point is to reiterate in all training conversations the importance of continued professional development. Encouraging the long-term reflexivity and personal growth that is necessary to be a culturally responsive educator is a key component of sustainability in professional development.

7.3.3 Examine the impact on students

To the extent that our study aims to fill a significant gap in the research literature about CRST in higher education STEM, there is an even larger dearth of evidence that examines exactly how CRST, specifically, impacts student experiences. We need to structure future professional development of STEM instructors with an assessment component that aims to close the loop on what works and what does not work in a culturally responsive science teaching in higher education.

8 Concluding remarks

Graduate TAs interested in teaching professional development and serving STEM undergraduate students were aware of and reported engaging in various forms of IST and CRST throughout their journey of learning about these teaching techniques. They reported strong interest in these teaching methods and described building connections through student information and using intentional active learning strategies. They also perceived structural and institutional barriers to successful enactment, including increased effort and conflict with the idea of equity vs. equality. Researchers and academics wishing to improve their undergraduate STEM education, especially at MSIs, should consider educating and empowering graduate TAs, and addressing their feedback, as a means to foster inclusivity and social justice in undergraduate STEM environments.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Human Subjects Committee of the UC Merced Institutional Review Board (IRB; Protocol ID 2020-3). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

KM: Formal analysis, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing, Data curation, Validation. HB: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. IW: Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. LB-J: Formal analysis, Funding acquisition, Writing – original draft, Writing – review & editing. EM: Formal analysis, Funding acquisition, Writing – original draft, Writing – review & editing. PK: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1418689/full#supplementary-material

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