Advancing Equity through Culturally Responsive Undergraduate Science Education: A Grounded Theory and Postcolonial Perspective of Culturally Responsive Science Teaching

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Abstract

Science as an enterprise has been and continues to be exclusionary, perpetuating inequities among whose voice is heard as well as what/whose knowledge is recognized as valid (Johnson, 2011). The National Science Foundation (2018) reports that women, minorities, and persons with disabilities are still vastly outnumbered in science and engineering by their White, male counterparts. These types of imbalances create a gatekeeping culture of inequity and inaccessibility, particularly for traditionally underrepresented students (Cheryan, Master, & Meltzoff, 2015). Science classrooms, especially at the undergraduate level, strive to mimic the broader practices of the scientific community and therefore have tremendous potential to perpetuate the exclusion of certain groups of people. They also have, however, the potential to be a catalyst for equitable participation in science. Utilizing pedagogies of empowerment (Hayden et al, 2011) such as culturally responsive science teaching (Ladson-Billings, 1994; Gay, 2010) in undergraduate classrooms can mitigate the gatekeeping phenomenon seen in science. Teaching assistants engage in more one-on-one time with students than most faculty in undergraduate biology education, yet minimal pedagogical training is offered to them (Tanner & Allen, 2006). Therefore, training for improved pedagogical knowledge is important for TAs, but training for culturally responsive science teaching is critical as TAs have broad and potentially lasting impact on students.

This study explores the ways in which undergraduate biology teaching assistants enact culturally responsive science teaching as well as the factors they share that influence their decisions whether or not to enact culturally responsive science teaching

(CRST). Using constructivist grounded theory methods (Charmaz, 2014) and a secondary critique from a postcolonial perspective (Bang, et al., 2012; Carter, 2006; Smith, 1999), this study examined teaching assistants' reflections, observation field notes, semi-structured interviews, and focus groups to develop themes surrounding their enactment of culturally responsive science teaching as well as their reasons for enacting CRST.

Findings from this study showed that undergraduate biology TAs enact CRST in ways described by four themes: *Funds of Knowledge Connections*, *Differentiating Instruction*, *Intentional Scaffolding*, and *Reducing Student Anxiety.* Additionally, findings supported the following as themes related to what factors influence TAs as they enact CRST: *Affordances, Constraints, TA Beliefs, and TA Identity.* Lastly, a postcolonial critique of the findings revealed that addressing issues of *settled assumptions* and *bounded knowledge* in science could lead to a decolonized approach to undergraduate science education and, specifically, CRST in undergraduate science spaces. These findings provide new insights into the ways undergraduate science education might be reimagined to create equitable science learning opportunities for all students.

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Chapter 1: Introduction

Even in the 21st century, we continue to see substantial disparities across those who comprise science disciplines. Traditionally unrepresented groups such as women and racial minorities enter and are retained in science fields at lesser degrees (National Science Foundation [NSF], 2018. Similar statistics are reported in undergraduate science classrooms, where a wealth of factors impact whether or not students are able to succeed in traditionally acceptable ways (Cheryan, Master & Meltzoff, 2015).

Culturally responsive science teaching – asset-based and student-centered pedagogies of empowerment – can lessen the educational debt experienced by students who have been historically underrepresented[1] in science disciplines (Ladson-Billings, 2006a, 2006b). The purpose of this study was to understand the processes of enacting culturally responsive teaching in undergraduate biology laboratory instruction and the factors that influenced teaching assistants' decisions whether or not to implement culturally responsive science teaching.

Statement of the Problem

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[1] Terminologies such as *underrepresented minorities* (URMs) are consistently used in academia and in education research, but persistently negative connotations associated with the term *minority* have started to incite a change in academic terminology (Mukherji, Neuwirth, & Limonic, 2017). For the purpose of this study and in consonance with its postcolonial grounding, *traditionally underrepresented students* will replace URMs. Traditionally underrepresented students in this study include populations of women, students of color, first-generation college students, and students with disabilities and/or accessibility concerns.

Science as a Gatekeeper. Science as an enterprise has been and continues to be exclusionary, perpetuating inequities among whose contributions are acknowledged as well as what/whose knowledge is recognized as valid (Johnson, 2011). The National Science Foundation (2018) reports that women, minorities, and persons with disabilities are still vastly outnumbered in science and engineering by their White, male counterparts. These types of imbalances create a gatekeeping culture of inequity and inaccessibility, particularly for traditionally underrepresented students (Cheryan et al., 2015).

Science classrooms, especially at the postsecondary level, strive to mimic the broader practices of the scientific community and therefore have tremendous potential to perpetuate the exclusion of certain groups of people. They also have, however, the potential to be a catalyst for equitable participation in science. Utilizing pedagogies of empowerment (Hayden, 2011), such as culturally responsive science teaching, in undergraduate classrooms can mitigate the gatekeeping phenomenon seen in science.

Training for Teaching Assistants. Teaching assistants engage in more one-on-one time with students than most faculty in undergraduate biology education, yet minimal pedagogical training is offered to them (Tanner & Allen, 2006). In a study conducted over an academic year, our research team at this Midwestern U.S. university found that experienced teaching assistants – those who have taught for one or more semesters – are more consistently concerned with being student-centered in their instruction, whereas new teaching assistants are focused on their presentation and appearance as teachers. New TAs start to become more student-centered in their teaching toward the end of their first-year of teaching (Barron, Brown, Patrick, & Cotner 2018). In the Biology Education

(BE) department, our research team works with TAs in the three areas of *Scientific Teaching* (Handelsmen, Miller & Pfund, 2007): active learning, assessment, and diversity. In this framework, active learning practices are those which actively engage the learner, assessment refers to specific tools utilizes to measure learning progress and/or achievement, and diversity recognizes and values the differences of the classroom (including students, educators, content, and teaching practices). While substantial focus has been placed on active learning in biology education research writ large, addressing inclusivity in undergraduate science spaces is an emerging field of research (Hocking, 2010). These types of trainings have the potential to catalyze equitable access and participation for traditionally underrepresented students in undergraduate science. Therefore, training for improved pedagogical knowledge is important for TAs, but training for culturally responsive science teaching is critical as TAs have broad and potentially lasting impact on students and teach a diverse range of students in terms of ethnicities, races, linguistic backgrounds, socioeconomic classes, etc.

Theoretical Frameworks

Two theoretical frameworks guide this study: culturally responsive science teaching (Gay, 2010; Ladson-Billings, 1994) and postcolonial theory (Carter, 2006; Loomba 2015). I detail both in this section, followed by a brief discussion of literature on training culturally responsive science TAs that conceptually framed the TA training sessions I designed for this study.

Culturally Responsive Science Teaching. For this study, I used the term "culturally responsive science teaching" to refer to pedagogies stemming from *culturally relevant pedagogy* (Ladson-Billings, 1994), *culturally sustaining pedagogy* (Paris &

Alim, 2014), and *culturally responsive teaching* (Gay, 2010). Nearly 25 years ago, Ladson-Billings proposed the concept of *culturally relevant pedagogy* (Ladson-Billings, 1994; 1995a) and transformed teaching practices to focus more broadly on successful classroom pedagogies. In doing so, she laid the groundwork for inclusive teaching that prioritized cultural heritage of students of color (Paris & Alim, 2014). Culturally relevant pedagogy is a pedagogy of "opposition" and "empowerment" (Ladson-Billings, 1995b), linking school and culture in ways that aim to improve academic successes, foster critical consciousness— a process of critiquing societal inequities via relevant issues — and support cultural competence in the classroom which give students opportunities to "honor their own cultural beliefs and practices while acquiring access to the wider culture" (Ladson-Billings, 2006, p. 36).

Reflecting on the vast array of research and conceptions built upon her work, Ladson-Billings (2014) cautions against the failure of some academics to fail to evolve with the changing landscape of education. She cites as progressive and appropriate Paris and Alim's (2014) *culturally sustaining pedagogy* which takes an even more critical and anti-oppressive stance to eliminate the "White gaze" (p. 86), the assimilative expectations placed on students of color to perform like their White counterparts (e.g., a student is considered successful only if they behave or achieve in ways congruent with White, dominant norms).

Culturally responsive pedagogy has been a pathway through which multiple students' backgrounds can be validated and even privileged in the classroom. For example, McCarty and Lee (2014) specifically center the conversation on Native American educational disparities, saying that Native American students face a system that is “interlaced with ongoing legacies of colonization, ethnicide, and linguicide” (p. 103). Furthermore, they remind us that while extant research in Tribal communities has focused *on* Indigenous peoples, work *with* Tribal communities is far rarer. Therefore, Native Americans need to reclaim educational realities and address issues of student success in ways that are congruent with cultural norms. *Culturally sustaining and revitalizing pedagogy* is grounded in efforts to decolonize classrooms such that students and community members exercise sovereignty, self-determination, and cultural and linguistic repossession. Likewise, and specifically pertaining to science teaching, *culturally congruent teaching* – privileging the cultural practices and ways of knowing of traditionally underrepresented students (Garroutte, 1999) and *cross-cultural pedagogies* – bridging cultural chasms by teaching and valuing shared cultural traits (Aikenhead & Elliot, 2010) are approaches to instruction that advance a postcolonial agenda that attempts to looks beyond Western science as the dominant way of knowing and bridge cultures (Jegede & Aikenhead, 1999).

Geneva Gay’s (2010) *culturally responsive teaching* focuses on improving classroom practices, with specific attention paid to curricular resources, for African, Latino, Asian, and Native American students. In culturally responsive teaching, instructional activities center around engaging practices that are transparent and build toward a classroom sense of community. Gay explains that teaching in this way, whether in the K-12 classroom or in teacher preparation classrooms, have benefits that are threefold, 1) it alerts students to expect a different kind of classroom than they’ve perhaps experiences before, 2) it clearly establishes expected behavior among classroom interactions, and 3) it creates a sense of “camaraderie” and a “community of learning where we assist one another" (p. 219) or in other words, a culture and community of respect. Instructional interactions and curriculum alike should promote students' positive self-perceptions and their cultural heritages should be validated. Assignments should not be impediments to student achievement, but rather opportunities for students to engage in different levels of learning processes, thereby allowing them multiple ways to demonstrate success. When preparing teachers, Gay (2010) anchors her culturally responsive teaching in "diversity and modeling" of culturally relevant pedagogy (p. 221) so that up and coming educators can see, experience, and practice what a culturally responsive classroom might look like when they themselves become the teacher. To that end, teachers who strive to be culturally responsive should engage in authenticity in choosing curricula, meaning it should be created or adapted in ways that reflect the multicultural and diverse dynamics of their classrooms.

While each of these approaches stem from varied epistemological foundations (e.g., postcolonial theory), they share a common theoretical construct: classroom pedagogies must be culturally informed and asset-based. Culturally responsive teachers are acutely aware of their students' needs in the classroom and strive to make appropriate adaptations if and when necessary (Brown & Crippen, 2017). Of bringing these knowledges to action in the classroom, Brown (2009) affirms that teachers use "curriculum materials as tools to convey and reproduce curricular concepts, forms, and practices" (p. 17). Indeed, there is a unique relationship among teachers' curriculum design processes, their knowledge of pedagogy and content, and their practices (Brown, 2009). Thus, bringing culturally responsive approaches into the curricular fold can be powerful (Gay, 2002; Villegas & Lucas, 2002). This is especially evident in science classrooms where "border crossings" – the chasms between home and scientific cultures and discourses – can be particularly difficult (Aikenhead, 1996; Lee, 2005). This proposal outlines specific strategies recognized in culturally responsive science teaching (CRST).[2]

Postcolonial Theory. Postcolonial approaches in education research seek to deconstruct and disrupt systems that have historically marginalized students (Asher, 2005; Carter, 2004), such as the epistemic violence inflicted on Native American children whose language, culture, and knowledges were effectively exterminated during the Boarding School Era of the 1800s and 1900s (Medin & Bang, 2014). These exclusionary processes are structural and cultural, and can be seen in the obstruction of access to educational opportunities at all levels - from explicit moves to reduce public education funding, for example, to more nuanced gatekeeping forces such as forging a narrow and exclusionary narrative of who *should* be among the educated (Carter, 2004). Postcolonialism acknowledges that identities and cultures are not static and that we live at the intersections of race, class, culture, gender, and nation (Asher, 2005). Furthermore, pushing beyond binaries (such as Western science *or* Indigenous ways of knowing) is a rigorous and self-reflexive practice informed by postcolonial thought (Smith, 1999). Therefore one of the central aspect of postcolonial theory is its focus on representation where by certain cultural meanings, epistemologies, methods, communication, identities, language, etc. are either ignored or reduced into colonizers' ways of being and doing (Loomba, 2015). Some of the key tenets of postcolonial theory include the growing of

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[2] *Culturally responsive science teaching* (CRST) will hereinafter be used as the umbrella term to represent pedagogies that share the common thread mentioned above.

cultural overlap and hybridity (Asher, 2005; Bang et al, 2012), awareness that there is a social, psychological, and cultural inferiority imposed by the colonizer[3] (Fanon, 1961), and struggle for ethnic, cultural, and political economy (Loomba, 2015; Said, 1995) and reclamation (Simpson, 2014; Smith, 1999; Tuck & Yang, 2012).

Science classrooms are prime examples of upholding these dichotomies by legitimizing only the Western science representation. Thus, science education research (and, therefore, subsequent pedagogies) still heavily grounded in positivistic epistemologies (Richardson, 2015) that maintain assumptions "bound to stable and unitary ideas of nation, culture, identity, comparison, and difference" (Carter, 2006, p. 681). Bang et al (2012) premise that we must *desettle* those assumptions in traditional science education in order to reclaim education spaces for students whose voices have been systematically and perpetually silenced through the exclusionary processes mentioned above. *Settled* expectations in science confine what is both explored and valued in science classrooms as well as place traditionally marginalized students in "untenable epistemological positions that work against engagement in meaningful science learning" (Bang et al., 2012, p. 302). Much of the same can be said for undergraduate science classrooms, where colonized, patriarchal systems that elevate Western science as superior and relegates culture to social sciences are still visible (Aikenhead & Elliott, 2010; Harding, 2008).

As the educational research community strives to re-envision science education, we must do so with the intent to liberate educational systems from the oppressive forces

[3] The term *colonizer* refers to the entities, processes, and people whose dominance remains as a legacy of imperialism and settler colonialism and is reinforced by the oppression those it/they colonizes (Fanon, 1961; Loomba, 2015)

that perpetuate a binary of colonizer/colonized, self/Other, and intellect/affect. This study was an active attempt to desettle science (Bang et al., 2012) and how it is taught at the undergraduate level. An important part of that endeavor was interrogating the teaching practices of teaching assistants and doing so through a postcolonial lens. My research questions were not postcolonial in nature, per se, but the implications upon which I drew were examined through and informed by postcolonial theory.

Training Teaching Assistants for CRST. When Ladson-Billings (2014) revisited the progress and limitations of work done surrounding culturally responsive pedagogies, she proclaimed that “culture is always changing” (p. 75) and asserted that education must change with it. It is time to expand the work of culturally responsive science teaching beyond the K-12 education space and into undergraduate science education.

One of the most popular movements in undergraduate science education right now is scientific teaching (Handelsman, Miller, & Pfund, 2007), which brings together active learning, equitable assessment, and inclusive teaching. While the inclusive teaching component discusses common culturally responsive concepts such as recognizing diversity in the classroom, it is enacted to a lesser extent than the other scientific teaching practices (Tanner, 2013).

Faculty and teaching assistants – who are generally responsible for laboratory components of undergraduate science classes – report similar struggles as K-12 teachers do when discussing culturally responsive instruction: they are insecure in their ability to do so and it’s difficult to enact in many science lessons (Hockings, 2010).

Research Questions

This study was guided by the following research questions:

1. In what ways do biology teaching assistants enact culturally responsive science teaching?

2. What factors do biology teaching assistants share that influence their decisions to enact culturally responsive science teaching?

Significance of the Study

A common limitation to culturally responsive science instruction is the cognitive load — the increased burden or effort needed for knowledge transfer to occur — teachers face when preparing to enact culturally responsive curricula (Belgarde, Mitchel, & Arquero, 2002), particularly if specific trainings aren't available or accessible. Furthermore, structures for such preparation in formal teacher preparation settings are sparse (Mensah, 2011). For example, teachers described uncertainty in exploring and drawing upon their students' funds of knowledge – the household and community-based skills and tools accumulated over time (Rodriguez, 2013) – and often cite feeling an overwhelming responsibility to tend to every students' funds of knowledge. Likewise, undergraduate faculty and teachings assistants, to whom funds of knowledge is even more abstract than culturally responsive or inclusive teaching, struggle to make those connections when their class sizes are large and their student populations are diverse (Tanner & Allen, 2004). Comparatively, similar limitations exist in undergraduate science education where the specific conversations of culturally responsive teaching have not quite yet emerged.

Like science teachers, beliefs and values strongly impact the ways in which undergraduate educators choose to incorporate particular practices (Brown, 2009), such as culturally responsive teaching. Accessible and inclusive undergraduate science education is still in its infancy (Hockings, 2010). In addition to being critical to attracting and maintaining students with diverse backgrounds and cultures in science fields, utilizing culturally responsive approaches like incorporating funds of knowledge becomes equally important when traditionally underrepresented students transition from high school to college (Jegede & Aikenhead, 1999).

Overview of the Following Chapters

In Chapter 2, I provides a review of the relevant literature guiding this study, specifically relating to culturally responsive science teaching and the role of teaching assistants in undergraduate science education. Chapter 3 follows with a description of the methodology used in this study, including the data sources, collection, and timeline, the context of the study, grounded theory methods of analysis, and a description of the postcolonial critique of the findings. Chapter 4 presents the findings for Research Question 1 and 2, which explore how TAs enacted culturally responsive science teaching and what factors they shared that impacted their CRST enactments, as well as presents the postcolonial critique of the findings. Lastly, Chapter 5 discusses the implications of key areas, areas of future research, and conclusions.

Chapter 2: Literature Review

In the following segments, I outline foundational pieces from the literature that grounded my study. First, I discuss three domains through which culturally responsive teaching has been enacted in science classrooms: general connections to culturally responsive science teaching, inclusive teaching, connections to funds of knowledge, and ties to sociopolitical consciousness. Next, I examine the ways in which biology teaching assistants in undergraduate science spaces have or have not been exposed to pedagogical training and, specifically, culturally responsive science instruction.

Culturally Responsive Science Teaching

In the following sections, I examine three domains within which culturally responsive science teaching can manifest in science classrooms: culturally responsive curriculum, utilizing funds of knowledge, and engaging sociopolitical consciousness.

Culturally Responsive Curriculum. Use of culturally responsive curriculum has been shown to be critically influential in empowering students (McCutcheon, 2002; Milner, 2011). For example, a study of African American students' perceptions of their teachers' cultural responsiveness revealed that they felt teachers were engaging in culturally responsive teaching when they incorporated "features of the students' cultural capital" into their curriculum (Howard, 2001, p. 145), but that teachers' curriculum by and large didn't reflect their broader ethnic experience. Similarly, and more pertinent to science education, Laubach, Crofford, and Marek (2012) endeavored to better understand Native American students' perceptions of scientists and found that an "overwhelming majority of students drew a scientist that was male, Caucasian, and working indoors" (p.

1787). They argue that using culturally responsive curriculum in science classrooms could alleviate such mismatches in students' perceptions of who scientists are.

While a variety of strategies exist to design culturally responsive curricula, I focus particular on those below that I perceive contribute to student empowerment and self-efficacy, two areas which are exceptionally important in repaying the educational debt (Bang & Medin, 2010; Gay, 2010; Ladson-Billings, 2006a; 2006b) owed to traditionally underrepresented students in science education (Mensah, 2011).

Multiple Ways to Demonstrate Intelligence and Competency. Lee and Buxton (2013) assert that the most effective ways to foster scientific literacy and English proficiency among English language learners is for teachers to anticipate varying levels of discourse ability with respect to formal science communication, adjust curricula accordingly, and build scaffolds that allow students to demonstrate competency along multiple time points. They argue that it is particularly important to reduce the language-related cognitive load. We, as scientists and as science educators, engage in a specific kind of scientific language and culture. Creating environments in the science classroom that validate students' rich and varied ways of knowing can bridge the road between those different discourses (Bang & Medin, 2010). By extension, in creating curricula that reflect these values, teachers should especially consider the type of assessments they utilize (Powell et al., 2012) and adapt them accordingly to promote multiple modes of learning (Villegas & Lucas, 2002). Such mechanisms can prove to be effective vehicles for student empowerment and self-efficacy in science.

Multiple Ways to Achieve Success. Calabrese Barton (2007) asserts that teachers play a critical role in preparing students to be successful in science, finding that unbalanced power dynamics perpetuate diminished self-efficacy in traditionally underrepresented students. Who is or who can become successful in science is often a product of classroom experiences that result in disproportionate feelings of self-efficacy (Darling-Hammond, 2010). Teachers have the ability to upend that status quo by providing multiple ways for students to demonstrate and achieve success (Atwater, Freeman, Butler, & Draper-Morris, 2010). Students can achieve success by engaging in collaborations wherein they have many opportunities to demonstrate knowledge and/or skills among their peers (Ladson-Billings, 1994).

Bransford, Brown, and Cocking (1999) unpacked the ways in which experts and novices differ in their abilities to understand information and demonstrate that knowledge, contending that experts – or expert learners - essentially can process and retrieve information more efficiently because they can associate new content with their existing conceptual frameworks. In science classrooms, collaborative initiatives can allow students to engage in an expert/teacher identity (Brown & Crippen, 2017) which can also help students learn new concepts by drawing on each other's expertise (Powell et al., 2012).

Finally, success in science can be achieved by providing opportunities for students to access and/or explain science in their home or dominant discourses (Powell et al., 2012). Gee (2014) describes discourses as falling within two main categories: "big D" Discourses that essentially underscore a person's "socially situated identity" (p. 47) such as a person's way of interacting with the world and "little d" discourses that are more commonly understood as a person's language and language interactions. The singular term *discourse* encompasses both of those categories for this purpose of this work.

Science has a discourse and a culture (Siry, Ziegler, & Max, 2012), but that requires that students adhere to one true or correct way to engage with that culture (Koomen & Barron, in press).

Science Experiences are Rigorous. Traditionally underrepresented students in science and engineering face a multitude of barriers even before entering the discipline – particularly in undergraduate science classes (Bang, Warren, Roseberry, & Medin, 2012). In a study about Native American students' experiences in such classes, Moyer et al. (2014) report that one of those barriers is Native students' perceived and/or lived experiences that faculty and other students view them as less academically inclined than non-Native students. Traditionally underrepresented students experience diminished expectations from their teachers and, often, tempered or watered-down curricula (McKinley & Gan, 2014). Enacting lessons – both in the classroom or the laboratory – where rigorous science experiences are upheld for all students is a critical component of sustaining self-efficacy in science (Tsurusaki, Calabrese Barton, Tan, Koch, & Contento, 2013). As described in Chapter 1, CRST has emerged as key focus area in advancing equity in science education in K-12 spaces. However, such a focus is missing in postsecondary science education.

Funds of Knowledge. Born out of a desire to shift the commonly held deficit perspective of bilingual Latino/a students' skills and achievements, *funds of knowledge* emerged as a theoretical and methodological construct by Luis Moll and Stephen Diaz in the 1980s (David, 2016). In their early studies, Moll and Diaz (1987) demonstrated that bilingual students held significant cultural capital that was often overlooked because of their minority status, and it was demonstrated particularly well when those students were assessed in bilingual settings. Students showed greater proficiency and gains in English language learning when they were able to incorporate their dominant language and it became clear to the researchers that achievement barriers faced by minority and working-class students were a "consequence of institutional arrangements that constrain students *and* teachers by not capitalizing on their talents, resources, and skills," (p. 302). In particular, Moll and Diaz were interested in the intersection of traditionally underrepresented students' skillsets and Vygotsky's Zone of Proximal Development theory, which posits that learners have an inherent ability, stemming from their social and cultural knowledges, to learn a concept or perform a task but cannot quite do so to completion until a *more knowledgeable other* aids them in that process (Moll, 2014). Sociocultural learning thereafter informed their research, leading to interventionist approaches in both research and teaching that many scholars have built from, making funds of knowledge a familiar part of education discourse (Combs, 2011).

During roughly the same time period, Vélez-Ibáñez and Greenberg (1992) worked to challenge the static conceptions of culture and introduce their interpretation of funds of knowledge with specific regard to the household practices of Mexican borderland communities. While their model was geared more toward economic responses and cultural reproduction, their intermingling of Bourdieu's (1977) notions of *habitus* – everyday behavioral patterns of households and communities – provided another entry point for education scholars seeking to better understand funds of knowledge and the potential application in classroom (Vélez-Ibáñez, 1989; David, 2016).

The next foundational literature of the funds of knowledge framework came from a paper Moll published in 1992 with a few graduate students (González, Moll, & Amanti, 2006). In it, they provided an ethnographic narrative of two teachers' methods in capitalizing on their students' rich and multi-faceted household knowledges and skills, articulating what that looked like in the classroom (Moll, Amanti, Neff, & González, 1992). One of the commonly held descriptions across recent literature refers to funds of knowledge as the skills and practices that are local to an individual's household or community and have accumulated over time (Clement, Fries, Postma, & Zhang, 2015; Llopart & Esteban-Guitart, 2018; Rodriguez, 2013). A closer look at how science teachers can access and incorporate their students' funds of knowledge is now examined.

Utilizing Funds of Knowledge in Science Classrooms. Calabrese Barton and Tan (2009) further the conversation, describing how students' everyday experiences and knowledges are valuable considerations for classroom instruction, especially if educators desire to practice culturally responsive science teaching or anti-oppressive pedagogies. Investigating a teachers' curriculum design and implementation in a 6th grade science classroom, their work revealed that students draw upon in a variety of funds while learning science: family, community, peer culture, and popular culture. Furthermore, by introducing new ways of engaging with science content that were informed by these funds, students "volunteered information" that "contributed to science talk" (p. 66). Walkinton and Bernacki (2015) contend that funds of knowledge when utilized in science curriculum, like Calabrese Barton and Tan's study, act as scaffolding mechanisms (Vygotsky, 1978) to foster better student attainment of science concepts. Likewise, Van Neil (2010) found that tailoring science classrooms to draw on students' individual and collective funds of knowledge make learning science content more fluid. Scholars further affirm that funds of knowledge pedagogies and curricula in science classrooms contribute to student empowerment and performance (Bouillion & Gomez, 2001; Carlone, Haun-Frank, & Webb, 2011; Lloyd, 2010; Upadhyay, 2009).

There are many tenets of the funds of knowledge framework within which we can examine science teaching (David, 2016). For example, Moll et al. (1992) explored how *actively* accessing students' household knowledge and practices could be directly incorporated in class, stressing the importance moving beyond simple or illustrative examples. Other scholars have focused on how such funds contribute to a larger, multicultural approach in teachers' instruction (Verdin, Godwin, & Capobianco, 2016). I now focus on accessing funds of knowledge to, 1) promote diverse knowledge and perspectives, and, 2) to foster positive science identities because those attributes are devalued and largely non-existent, respectively.

Diverse Knowledge and Perspectives. Many students of color have a sense of belonging uncertainty when it comes to engaging in science and science practices (Walton & Cohen, 2007). These doubts, Smith et al (2014) argue, are barriers that have accumulated through colonizing education structures and exist across populations with knowledges and perspectives that appear different than the Western science model. This can be seen in Native American students who navigate Western science while also ascribing to Indigenous ways of knowing about the world. In order to work against this archetype, curriculum in science teaching should not only be inclusive of diverse knowledges and perspectives, but should validate them in instruction and assessment (Lee, Yen. & Aikenhead, 2012).

Positive Science Identities. Tytler (2014) describes that there are several theoretical constructions in science education, which are more related than is often noted in the literature. They include favorable attitudes and perceptions of who scientists are and what they do, enjoying science and science learning experiences, and self-efficacy in science. Yet when we look for these types of attitudes and identities in students of color, and in Native American students in particular, they are far behind those of their White classmates (Lee, 2012). When teachers supported their students in applying their own funds of knowledge to real science issues, Cook (2014) found that those students had a deeper connection to the content and increased perceptions of self-efficacy. Furthermore, students whose teachers engaged in funds of knowledge curricular strategies demonstrate more complex scientific reasoning during inquiry-based problem solving than when they didn't use their funds of knowledge in those same kinds of activities (Irish, 2013). Likewise, Lloyd (2010) reported that engaging in rural students' funds of knowledge allowed them to feel like their skills were validated and that their science content knowledge was important and accurate. Broadly speaking, engaging in funds of knowledge as an active and asset-based teaching practice can lead to higher self-efficacy in science and more positive science identities among students of color (Carlone et al., 2011).

Funds of knowledge connections are both representative of the pedagogies of empowerment underscored in CRST (Gay, 2010; Ladson-Billings, 1994) as well as mechanisms for cultural and epistemic reclamation (Medin & Bang, 2014). Thus, in this review of the relevant literature, FoK connections are described at length because of their potential critical role in advancing equity in science education both through CRST and from a postcolonial approach. An emerging body of scholarship focuses on these areas in

K-12 science education (Bang et al.; Carter, 2006; Upadhyay, 2009), but little has been explored in postsecondary science education.

Sociopolitical Consciousness. Ties to sociopolitical consciousness in CRST are those which foster a critical consciousness (Ladson-Billings, 1995) about broader systems of social inequity through relevant issues (Ladson-Billings, 2006).

Developing a citizenry engaged in decision and action. At the turn of the 20th century when science instruction was largely prescribed and in constant contention with classicist and religious-based education (DeBoer, 1991; Kliebard, 2004), John Dewey called for the need to make science relevant to students (Dewey, 1919). By weaving his assertions about the relationality of nature and the human condition together with his thoughts on inquiry, he proclaimed that science was a "method of thinking, an attitude of mind (Dewey, 1910, p. 1). We see relevant and repeating themes today in such calls to action as the National Research Council's (2012) strive to make *science for all* and also in movements that inspire student agency through pedagogy. Powell et al. (2012) assert that science instruction should provide opportunities for students to "contribute, inform, persuade, and have a voice in the classroom, school, and beyond" (p. 12). Creating opportunities for students that inspire social action through informed decision-making is a practice of empowerment (Suriel & Atwater, 2012). Democratic science teaching through *critical science agency* (Basu et al., 2007) is a key area of study through sociopolitical consciousness connections are examined in K-12 education spaces, yet such work is lacking in postsecondary science education.

The Role of Teaching Assistants in Undergraduate Science Education

Teaching assistants comprise a substantial portion of the education force in undergraduate science classes and labs (DeChenne & Enochs, 2010) and contribute greatly to the impact science instruction has on students (Vereleger & Valasquez, 2007). While there have been decades of research on teaching assistants (TAs), it has centered on TAs and TA training in non-STEM disciplines, such as psychology (Prieto & Meyers, 1999). In the following sections, I review the work that has been done with TAs as well as the areas that are less explored. Then, I discuss the potential impacts that training TAs in culturally responsive science teaching can have on undergraduate science education.

TA Training: A Review of Existing Programs. Teaching assistants spend more one-on-one time with students in undergraduate science spaces than faculty and yet research shows they are vastly underprepared for being a teacher (Golde & Dore, 2001; Luft et al, 2004). A variety of training for TAs has be implemented and studied (Prieto & Scheel, 2008); the following segments describe such work.

TA Cognition. Many models of TA training have centered around the cognitive changes TA experience as they engage in a training program or professional development (Reeves et al., 2016). Patrick, Barron, Brown and Cotner (2018) found, for example, that easy assessment – a popular active learning technique – was the most valued and most frequently used training topic for TAs who participated in a workshop about active learning. Other studies in inquiry-based TA training have shown levels of knowledge and comfort-level vary according to both characteristics of the trainings as well as the TAs themselves (Bowman et al, 2013). Likewise, much research has delved into what influences TA self-efficacy for various aspects of teaching (DeChenne, Koziol, Needham, & Enochs, 2015).

TA Teaching Practice. Reeves et al. (2016) contend that TA cognition is intrinsically linked to teaching practices which warrants the extant and continued research into their behavior and cognition as they relate to teaching practices. Planning, instruction, and assessment are three areas of such extensive research (Wyse, Long, & Ebert-May, 2014). The role of the laboratory TA in science courses is especially critical, given the importance of lab-based activities to the development of science-process skills in undergraduates. In short, the teaching laboratory is where many undergraduates first learn how to *do* science. Consequently, calls for reform (e.g., Brewer & Smith, 2011; National Research Council, 2010) highlight the importance of the teaching laboratory as a critical site. Specifically, it has been argued that students engage in authentic scientific practices via two active learning experiences: inquiry-based laboratory activities (Brickman, Gormally, Armstrong, & Hallar, 2009; Minner, Levy, & Century, 2010) and course-based undergraduate research experiences (or CUREs; Ballen et al., 2017; Auchincloss, et al., 2014). Effective facilitation of these experiences requires instructors—often TAs—to be familiar with desired outcomes as well as the capacity to engage their students in exploration, experimental design, data collection and interpretation, and findings communication (Cheung, 2008). Science experiences that are inquiry-based and authentic can also promote inclusion (Espinosa, 2011). Thus, to broaden science participation, TAs should learn some basic techniques for inclusive teaching, such as how to elicit input from all students (Tanner, 2013).

It is not shocking, given how few science faculty employ *Scientific Teaching*, that novice instructors — such as undergraduate TAs — may be even less aware of these techniques and less likely to use evidence-based teaching techniques. Teaching assistants (TAs) are prime candidates to engage in these kinds of initiatives as they often interact with students more closely than faculty (Romm, Gordon-Messer, & Kosinski-Collins, 2010). Several *Scientific Teaching*-focused programs report programmatic assessment efforts, either documenting the need for training, TA perceptions of the training, or changes in teaching behaviors associated with training. However, efforts to describe the teaching-related concerns of these novice science educators during their initiation into laboratory teaching have been explored minimally explored.

More critically, efforts to initiate and develop awareness and skills in enacting culturally responsive science teaching have yet to be explored at all in undergraduate science education. Despite the wealth of research that has been and continues to be conducted surrounded biology teaching assistants, there exists a significant gap in the literature in relation to training TAs for culturally responsive science teaching at the undergraduate level. Moreover, while some studies are beginning to emerge that discuss how to make undergraduate science more inclusive (Vergara et al., 2014), a recent review of the literature has revealed that such strategies for equitable science education through culturally responsive science teaching have not yet been extensively modeled for teaching assistants.

Chapter 3: Methodology

The following chapter examines the research design of the study. The purpose and research questions are first described, followed by the context of the study including brief biographies of participants and an in-depth overview of the TA program. Data sources, data collection and data analysis follow with the conclusion of the chapter discussing researcher positionality and study trustworthiness.

Purpose

The purpose of this study was to understand the processes of enacting culturally responsive teaching in undergraduate biology lab instruction and the factors that influenced teaching assistants' decisions whether or not to implement.

Research Questions

To explore the ways in which biology teaching assistants engaged in utilizing culturally responsive science teaching in their labs, this study was guided by the following research questions:

1. In what ways do biology teaching assistants enact culturally responsive science teaching?
2. What factors do biology teaching assistants share that influence their decisions to enact culturally responsive science teaching?

Research Design

This study applied a grounded theory methodology to address the research questions. Grounded theory is an approach to qualitative analysis that aims to develop an abstract or theoretical understanding of an experience or set of experiences (Charmaz, 2006; Glaser & Strass 1967; Strauss & Corbin, 1998). In her updated edition of *Constructing Grounded Theory*, Charmaz (2014) outlines the main tenets of grounded theory as a methodology:

> "Grounded theory methods consist of systematic, yet flexible guidelines for collecting and analyzing qualitative data to construct theories from the data themselves. Grounded theory begins with inductive data, invokes iterative strategies of going back and forth between data and analysis, uses comparative methods, and keeps you interacting and involved with your data and emerging analysis" (p. 1).

As described above, the views and actions of the teaching assistant participants (Strauss & Corbin, 1998) in this study were the foundation for developing a localized theory that was grounded in the real-life actions taking place in undergraduate science teaching, making it an ideal template for grounded theory.

A core element of grounded theory is theoretical sampling. According to Corbin and Strauss (2015), theoretical sampling is the process of collecting information or additional data based on the properties and dimension of an emerging theme. Detailed examples of how and when theoretical sampling occurred is described in the *Data Analysis* section of this chapter. The purpose of theoretical sampling is for the development of an emerging conceptual framework (Glaser & Strauss, 1967) such that the data become saturated or, in other words, when new concepts no longer emerge (Charmaz, 2014). The term *theme* refers to the product of grounded theory analysis wherein individual codes and categories are intentionally reconstructed and elevated to reflect an abstract conceptualization (Charmaz, 2014). Collectively, these emerging conceptualizations can be used to generate a broader conceptual framework with which to describe the findings. This approach to understanding the *processes of* and the *reasons* *for* enacting culturally responsive science teaching is methodologically appropriate because no such conceptual framework has been developed extensively for teaching assistants. Charmaz's (2014) approach to *constructivist grounded theory* offers some flexibility in that it shifts the methodology slightly away from Glaser and Strauss' post-positivistic leanings, allowing for poststructural, critical, and/or postcolonial epistemologies to inform research using grounded theory. Constructivist grounded theory "shreds notions of a neutral observer and value-free expert" (Charmaz, 2014, p. 13) which diverges from the objectivist work of Glaser and Strauss and even the early work of Strauss and Corbin in that it acknowledges that research is a construction that occurs within specific contexts (Bryant & Charmaz, 2007). Specific to this study, constructivist grounded theory analysis allowed me to later interrogate the contexts of my findings from a postcolonial perspective by looking closely at the social constructions of the conditions under which science learning and science teaching occur in undergraduate education.

Context

Instructional context: Training for culturally responsive science teaching. Teaching assistants vary in their ability and concern for enacting student-centered teaching practices (Barron et al., 2018). Culturally responsive science teaching can be a powerful pedagogical tool yet it requires adequate and appropriate training in order to reduce the cognitive load – the amount or intensity of mental resources used to process new information – of the instructor (Belgarde, Mitchel, & Arquero, 2002).

In this study, teaching assistants engaged with weekly training modules that outlined strategies for culturally responsive science teaching and challenged them to implement those strategies in their classroom and/or lab. Additionally, the training sessions aimed to disrupt prevailing ideas of science teaching, challenge and expand TAs' ideas and beliefs about culturally responsive science teaching, and develop a critical dialogue surrounding issues of equity and access in science learning. Such strategies included but were not limited to: how people learn, science as a way of knowing, and place-based learning and social action. The weekly training sessions were held every Friday morning from September 21, 2018 to December 7, 2018. Each session followed a similar format that was intended to scaffold the TAs learning about culturally responsive science teaching as well as provide a safe space within which they could engage with each other about how they envisioned enacting culturally responsive teaching in their labs. Table 3.1 provides an overview of the focus for each weekly lesson, how it connected to culturally responsive science teaching, and specific resources provided to the TAs. Each session's activities were grounded in historical and current literature on culturally relevant and responsive pedagogies and formulated dynamically and in conjunction with how TAs could enact the techniques we discussed. Appendix A includes an expanded version of Table 3.1 including weekly brainstorming and goalsetting prompts for TAs.

Table 3.1

Design of Weekly Training Sessions for Culturally Responsive Science Teaching

Training Date	Overview of the Training	Connections to Culturally Responsive Science Teaching	Resources Provided
September 21, 2018	Introduced adult learning concepts. Outlined key findings on adult learning theory including 1) how students' preconceptions about	Differentiating instruction as a result of understanding students' pre/misconceptions; creating conceptual frameworks that allow	Provided TAs with examples of conceptual frameworks and ways to elicit students' preconceptions from *How People Learn*

	content influence their learning, 2) retrieval of knowledge requires a conceptual framework or "hook" Bransford et al. (2000).	multiple ways for students to demonstrate competency and intelligence in the lab (Sternberg, 2007)	(Bransford et al., 2000)
September 28, 2018	Continued with Bransford's key findings on adult learning, specifically how metacognition can aid in learning. Began introduction to funds of knowledge and how to begin centering personal and student funds of knowledge in instruction.	Equitable science learning spaces provide students with opportunities to develop agency in their learning (Carlone et al., 2011) and engaging students in metacognition is a way for them to do so. Validating students' funds of knowledge in the lab can make science learning more accessible to students (Moll et al, 1992).	Provided TAs a handout that introduced the historical and current scholarly work surrounding accessing and drawing up funds of knowledge in science learning spaces.
October 5, 2018	Continued discussing funds of knowledge in science learning spaces, focusing specifically on how identifying, utilizing, and connecting with students' social and cultural resources "helps a teacher to avoid the pitfalls of an exclusionary" classroom or lab (Upadhyay, 2005, p. 103).	Funds of knowledge connections can transition a potentially exclusionary learning environment into an inclusive space.	Provided TAs with examples of what using students' funds of knowledge looks like, including scenarios and strategies (Bouillion & Gomez, 2001)
October 12, 2018	Building on funds of knowledge, I reiterated the focus on equity in science education and began discussing how identity of students as	Creating science learning environments where students have opportunities to build positive science identities contributes to	Provided TAs with the Carlone, Haun-Frank and Webb (2011) article as well as Tytler (2014) reading.

	knowledge producers (Tytler, 2014) is an important aspect of culturally responsive science teaching.	inclusive and equitable teaching (Carlone et al., 2011)	
October 19, 2018	Introduced TAs to pedagogical content knowledge (PCK) as a specific aspect of instruction they could focus their culturally responsive teaching efforts if they desired. Continued the conversation about how our identities shape how we teach and how we learn.	Continued focus on building positive science identities.	Provided TAs with an identity profile assignment to complete but also that they could adapt to elicit more information about their students' identities.
November 2, 2018	Continued discussing PCK as a way to examine where the TAs strengths and confidences were surrounding their content and ability to enact culturally responsive science teaching.	General connections to asset-based pedagogies surrounding typically difficult science content.	Provided TAs with specific examples of equitable assessments (Learning Goal Inventory, "Muddiest Point" (Keeley, 2008)).
November 9, 2018	Introduction to critical science agency (Basu et al, 2011) and sociopolitical consciousness in science teaching (Mensah, 2011; Powell et al., 2012; Suriel & Atwater, 2012)	Equitable and empowering science teaching can draw upon critical science agency and sociopolitical consciousness to expand and/or deconstruct traditional outcomes in science education (Basu, Calabrese-Barton & Tan, 2011; Calabrese Barton et al., 2011).	Provided students with handouts from chapters of Democratic Science Teaching (Basu, Calabrese-Barton & Tan, 2011)

November 16, 2018	Pause for TA reflection and opportunity to engage in their own metacognition.	Drawing on being culturally connected (Esign, 2003) in a broad sense to create inclusive science lab spaces.	Provided TAs with an annotated bibliography of articles from major focal areas of culturally responsive teaching including cultural competence (Ladson-Billings, 1995), critical consciousness (Basu & Calabrese-Barton, 2007), language supports (Luykx & Lee, 2007), social action (Bouillion & Gomez, 2001), and care and respectful relationships (Mensah, 2011)
November 30, 2018	Discussion about learning as a sociocultural and situated process; focus on how students negotiate forms of participations and identities within this process.	Connecting inclusivity in science teaching to empowering student voice in the lab and deconstructing the myth that the teacher/TA is the single knowledge-holder.	Provided students with Bang, Warren, Roseberry and Medin's (2012) work on desettling expectations in science.
December 6, 2018	Closing conversations about culturally responsive science teaching and how TAs view themselves as science educators.		Provided TAs with examples of what culturally responsive science teaching looks like when specifically responsive to a particular group (i.e., Minnesota Native Americans).

Participant and selection criteria. This study was conducted at a large public research institution in the Midwestern United States. As one of the lead instructors of a

TA training program for non-majors biology TAs, I had the opportunity to work with teaching assistants across all levels of biology lab and lecture sections. For this study, experienced, undergraduate teaching assistants (> 1-year previous TA experience) who were teaching an introductory biology lab during the data collection timeline were invited to participate in this additional training specific to culturally responsive science teaching. Introductory non-majors biology courses taught by the TAs included a general biology and ecology survey course, an environmental biology course, and a foundations of biology course. TAs from all courses were offered the opportunity to participate in the study as long as they were classified as experienced. Those teaching assistants (N=4) who committed to participate in this study are described next. The names used for this study were pseudonyms selected by the participants. Because this study aimed to understand the processes and/or actions that TAs shared for being able to enact culturally responsive teaching, the biographies below include self-reported factors that influenced their views on teaching and desires to be TAs. Collectively, the TAs shared that in aiming to enact culturally responsive science teaching in their labs, they were hoping to be responsive and inclusive to students who were non-majors (i.e. majoring in a field of study other than biology) as well as first-generation college students.

Chad. Having taught for four consecutive semesters prior to the start of the study, Chad was considered a seasoned TA by her peers and the faculty who coordinating the course schedule for the lab course she taught, *Human Biology*. At the time of the study, Chad was a senior preparing to graduate with a double major in Physiology and Economics and a minor in neuroscience. When asked about her reasons for wanting to be a teaching assistant, Chad said that she was particularly interested in teaching non-majors biology students because she was also a non-major when she took her first biology course as a student, “For most students, this is the only biology course they are going to get, so I like to teach them things they can get excited about,” (Post-semester interview, December 11, 2018). Chad expressed her interest in continuing in both biology and education and planned to apply to medical school, beyond which she hoped to work in community health education.

Katie. Engaging and energetic, Katie was an experienced teaching assistant at the start of the training, having taught *Introduction to Biology,* for three semesters prior. Katie came to be a teaching assistant as part of her personal and career aspirations to combine her love of science with her multi-disciplinary studies in literature, social change, and language. A significant part of her role as a TA was defined by her personal beliefs that learning should be an engaging and eternal process. Of being a TA of a non-majors biology lab, Katie said, “It is [my job] to find the gifts and talents that every person brings and use those gifts to engage them – the teacher is not the gift, the students are” (Post-semester interview, December 13, 2018). In addition to being culturally responsive to non-majors and first-generation college students, Katie also noted she hope to be responsive to students whose first or dominant language was not English, citing the potential additional barriers of learning the “language of biology” while also learning English (Post-observation interview, October 2, 2018). At the close of the training, Katie had been accepted into a Master’s of Education program and planned to continue in the field of science education.

Mitch. When I asked Mitch why he had decided to participate in this study, his response was that he was persistently “frustrated when students say ‘I’m not a science person' because it's not that they can't be, it's that resources are often prohibitive," (Post-semester interview, December 6, 2018). While Mitch admitted he is a self-proclaimed "science person" he simultaneously pointed out that his upbringing with parents who went to college as well as his degree focus in biology were instrumental in that identity development. Teaching non-majors in *Introduction to Biology*, however, Mitch said he became aware of how science course structure or content could sometimes be barriers to developing positive science identities in students, which inspired him to continue pursuing student-centered teaching practices. Mitch, a senior, planned to apply to graduate school and continue teaching undergraduate science.

Greg. After teaching *Perspectives in Biology* for two semesters and engaging in some TA training surrounding scientific teaching, Greg approached me to participate in training for culturally responsive science teaching. He was most interested in developing curricular products that were "engaging so that students feel like they are spending their time and money on valuable experiences," (Post-semester interview, December 11, 2018). Greg focused on improving his teaching because he, like many other science majors, experienced lack luster and/or ineffective teaching typically in the format of lectures. As an interactional and motivational TA, Greg approached his teaching from the perspective of the learner, meaning he made teaching decisions based on how he felt they could positively affect science learning for his students. After graduating, Greg hoped to go on to graduate school after taking a year or so off to work in industry.

Data Sources

Multiple data were collected to address the study's research questions. To address Research Question 1, the main data sources included TA reflections, observation, post-observation interviews, and focus groups. To address Research Question 2, the main data sources consisted of TA reflections, training artifacts, and focus groups. Table 3.2 outlines my data collection timeline and the research questions each data source aimed to address. The following subsections discuss each data source in detail.

Table 3.2

Data Collection Timeline

		Project Timeline						
Data Sources	Question Addressed	Sept. '18	Oct. '18	Nov. '18	Dec. '18	Jan. '19	Feb. '19	March '19
TA reflections	RQ 1 & 2	X	X	X	X			
Observations	RQ 1	X	X	X	X			
Post-observation interview	RQ 1	X	X	X	X			
Training Artifacts	RQ 2	X	X	X	X			
Focus Groups	RQ 1 & 2				X			
Member Checking	RQ 1 & 2					X	X	X

TA Reflections. Teaching assistants were asked to complete written reflections based on the weekly training content and their instruction as it related to CRST. Specifically, these reflections were structured to prompt the TAs to think critically about how they enacted aspects of culturally responsive science teaching as well as reflect on how that enactment went in their labs and classrooms. TAs completed 10 reflective writing exercises – each with the same prompts – over the course of the semester and for each module week. These prompts were:

1. *Considering what we've talked about so far (and your goals from this week), what kinds of things have you done this week that you perceive as culturally responsive and inclusive teaching strategies?*
2. *Can you provide specific examples of ways you were able (or not able) to enact those strategies?*
3. *What factors made it easier to teach those strategies? What factors made it more difficult?*

Observations. I completed in-lab observations of each TA's instruction to document the variety of ways that TAs enacted culturally responsive science teaching. I conducted these observations each week following the Friday training sessions, documenting both teaching moments that related to the work we discussed in training as well as teaching moments that reflected other inclusive practices. Figure 3.1 details the general focus areas I looked for while observing each TA. These areas relate broadly to the weekly trainings and are grounded in evidence-based literature about effective CRST practices (Brown, Barron, & Rozowa, in review). As a participant observer, I made myself available to the TAs during the lab to be a mentor and sounding board for ideas if they felt they needed direction with their instruction. I made note of these types of interactions in my observation field notes and incorporated them into my analytic memos when appropriate. An example of my observation field note document is illustrated in Appendix B. In total, each TA was observed 10 of times. Video and audio recordings were collected at the same time and later used to verify and/or clarify information I documented in my observation notes.

Focus Area	
I. General Culturally Responsive	**A. Multiple Ways to Demonstrate Competency & Intelligence**
	a. Do TAs provide ways for students to draw on their "cultural capital" when solving problems?

Connections	b. Does the TA provide scaffolds to allow for varying levels of discourse ability?
	c. Do TAs create spaces where students' ways of knowing are validated in the lab/classroom?
	B. Multiple Ways to Achieve Success
	a. Do students have opportunities to engage in collaborations and take on various roles?
	b. Can the students utilize and/or build on their identities as experts/teachers during lab/class activities?
	c. Can students access and/or explain science content, concepts, and/or processes in their home or dominant discourse?
	C. Science Experiences are Rigorous
	a. Do TAs uphold rigorous science experiences in lab/class for all students?
II. Funds of Knowledges Connections	**A. Diverse Knowledge and Perspectives**
	a. Are students' home and community funds of knowledge utilized and validated in the lab/classroom?
	B. Positive Science Identities
	a. Do classroom or lab in scientific engagement allow students to express their own views and beliefs about what scientists are and look like?
III. Sociopolitical Consciousness Connections	**A. Drawing on local/regional/community-based problems**
	a. Can students develop awareness of local, regional, or community issues and develop decision-making skills action by doing so?

Figure 3.1 Questions grounded in CRST literature that guided weekly observations (adapted from Brown, Barron, & Rozowa, in review).

Post-Observation Interviews. Following each in-lab observation, I conducted brief, semi-structured interviews with individual TAs. These interviews were meant to be relatively short and gain insight into the TA's immediate reactions of their teaching that day. Charmaz (2006) stresses the importance of collecting data that is adequate enough to glean "detailed descriptions of a range of participants' views and actions" (p. 19). Post-observation interviews allowed me to document both what processes were occurring as they were teaching as well as their views about their teaching. During these interviews, I asked questions about how they felt their instruction went. More specifically, how the TAs felt about their in-the-moment decisions to enact culturally responsive teaching practices. Questions included, *How did you feel your instruction went today, specifically related to culturally responsive teaching?*, *How did you feel you were able to attain your culturally responsive teaching goals for this week?*, and *In what ways were you not able to meet your goals?*

Training Artifacts. During the weekly trainings, I compiled all materials utilized. These included: products of short writing exercises, brainstorming and planning documents. In part, weekly writing and discussion exercises were assigned to TAs for their own learning and reflection as culturally responsive science educators. The brainstorming prompts (Table 3.3) were assigned as a data source for Research Question 2 – to better understand their reasons for enacting culturally responsive science teaching in their labs. Appendix C illustrates all the writing and brainstorming prompts the TAs were assigned each week.

Table 3.3

Example of Weekly Brainstorming Prompts for Teachings Assistants

Date	Writing Prompt
September 21, 2018	How might you engage your students' prior knowledge? What steps can you realistically take to do that?
September 28, 2018	How do you solve a problem? What are the steps that you take? Why those steps?
October 5, 2018	Also, how can you intentionally and meaningfully connect your knowledge and experiences to your lesson/teaching next week?
October 12, 2018	What does success & competency in science look for your students?
October 19, 2018	What topics do you feel the most confident about teaching? In what ways are you confident? Why?

November 2, 2018	Can describe your views, thus far, on culturally responsive & inclusive teaching?
November 9, 2018	Is there one lab or portion of a lab where this might be easier to enact CRST? What do you see as barriers to this?
November 16, 2018	Why are you interesting in being inclusive, culturally responsive, etc.?
November 30, 2018	What kinds of things (collaborations, interactions, engaging, etc.) has been most influential through your learning process of culturally responsive teaching?
December 6, 2018	To whom is your instruction culturally responsive?

Focus Groups. At the close of the training, I convened a focus group to share collectively how the process of training and implementation had went for the TAs. Focus groups can often serve as points of triangulation, a process critical to being able to make comparisons between and across data (Charmaz, 2006). Similarly, member checking to determine accurate and genuine representation of TAs' views and actions was conducted. During the focus group, TAs were asked questions about what their major perceptions of CRST were, how they felt they enacted CRST in their labs throughout the semester, and the things that influenced their ability to enact CRST. The focus group was 65 minutes in duration and was audio-recorded. Later, I transcribed the recording verbatim.

Data Analysis

Congruent with the aims of the study – to identify and describe the properties and dimensions of what culturally responsive science teaching can look like in undergraduate science education – grounded theory (Charmaz, 2006; Strauss & Corbin, 1998) approaches were used to analyze the data. Though acknowledging that the researcher enters the research space already sensitized to the topics, participants, and/or processes under investigation, grounded theory methods assume minimal or no preconceptions about the potential findings (Glaser, 1978). Therefore, it is by nature an inductive process (Mills, Bonner, & Francis, 2006). Throughout the data collection timeline and per the nature of grounded theory analysis, I engaged in the iterative process of examining each data source as they were collected and creating analytic memos (Charmaz, 2006; Corbin & Strauss, 1990).

I will now detail how each research question was addressed by applying the grounded theory methods of open coding and focused coding, axial coding, and theoretical coding (Strauss & Corbin, 1998).

Analyzing Teaching Assistants' Enactments of Culturally Responsive Science Teaching (RQ1). Open coding is a process by which "concepts are identified and their properties and dimensions are discovered in data" (Strauss & Corbin, 1998, p. 101). The purpose of open coding is to break down data into "discrete parts" (Saldana, 2015, p. 115) in order to examine them and compare them. It precedes focused coding, referred to in this chapter as "line-by-line coding," which is an intermediary step in between open and axial coding that leads to the development of potential categories or sub-categories without forming strict boundaries (Saldaña, 2015). Open and line-by-line are the foundation of axial coding, which is the process of reassembling data into categories by examining and comparing their properties and dimensions.

In order to examine how teaching assistants enacted culturally responsive science teaching, I began open coding by looking across TA reflections and my observation field notes for specific indicators – statements, teaching moments, phrases – that I could use in the development of categories. Strauss and Corbin (1998) contend that an in-depth and microanalytical approach is critical during this stage of analysis. During open coding, I first utilized a holistic approach to (Charmaz, 2006) by which I looked across larger sections of data for salient indicators culturally responsive science teaching. To do this, I examined the TA reflections and my observation notes for each TA. Table 3.4 is an example of how I engaged in open coding and writing analytic memos for Mitch's weekly reflections. The prompt that Mitch was responding to in this table was *Considering what we've talked about so far (and your goals from this week), what kinds of things have you done this week that you perceive as inclusive teaching strategies?*

Table 3.4

Example of Open Coding and Analytic Memos for Research Question 1

Date	Source: Weekly Reflection Text	Open Codes	Analytic Memos
October 4, 2018	"Mostly, I tried to defuse [sic] what can be an uncomfortable lab - they took an exam and a quiz that day, they had to spit in a cup, and used new techniques like dilution plating and para-filming that can be frustrating. I did try to avoid saying "bad bacteria," and instead use more objective terms like "cariogenic." Also, using humor to defuse [sic] what can be an awkward lab (spitting in a cup). Finally, showing that a technique can be difficult and that's ok, such as when the parafilm kept breaking as I was doing my demonstration."	Make students comfortable Humor	"Mitch used humor to make students more comfortable – look for instances of this across all TAs"
October 10, 2018	"I tried to really encourage group participation in a way that doesn't put students on the spot. I've really had trouble with students speaking up and in a feedback survey I provided, one student said specifically that they wished I wouldn't wait for so long for someone to answer question, because they usually know it but	Ease student anxiety Prior knowledge	"Mitch is very student-centered – keep looking at how TAs are student-centered versus culturally responsive and where they overlap"

	don’t want to speak up. I also continued to try and bring in students past experiences and knowledge.”	

Next, I engaged in line-by-line coding of each of the data sources for each TA using the qualitative analysis software HyperRESEARCH™. Line-by-line coding means that I examined each line of every data source and assigned codes to words or phrases that I perceived to be important indicators of how TAs enacted CRST. Using Mitch’s October 12, 2018 reflection, Figure 3.2 demonstrates what line-by-line coding looked like in HyperRESEARCH™ for Research Question 1. In the right column, phrases and sentences related to Research Question 1 have been highlighted; in the left column, these phrases and sentences are assigned a label, or “code,” intended to communicate the message conveyed (e.g., “encouraged group participation”).

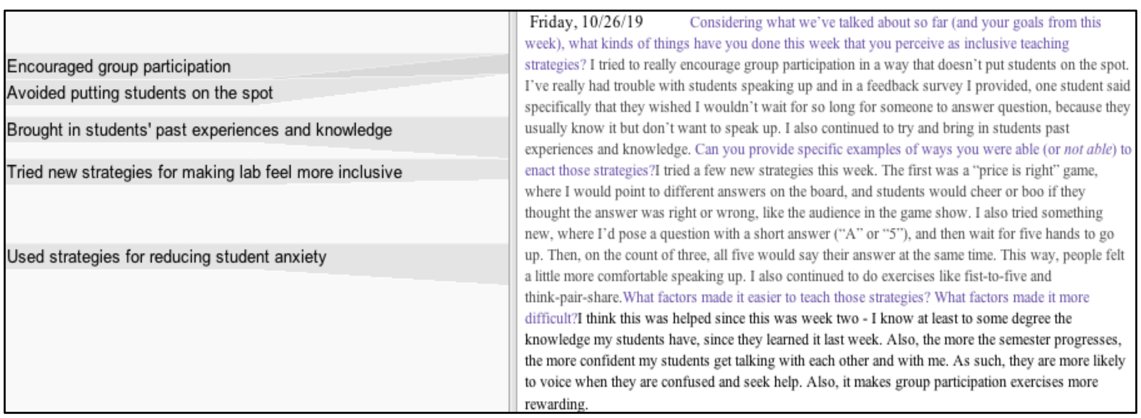

Figure 3.2 Example of line-by-line coding in HyperRESEARCH™.

I completed this process for my weekly observation and field notes, the TAs’ weekly reflections, which served as a self-report of how each TA felt they enacted culturally responsive science teaching, post-observation interviews, and focus groups. In order to be systematic in my coding process, I coded each data source, one at a time, for all TAs before moving on to the next one. I started with line-by-line coding for the TA reflections for Mitch, then Chad, then Katie, and lastly Greg. I moved on to my observation field notes and completed the same process and then repeated for the post-observation interviews. Lastly, I completed line-by-line coding for the focus group notes. I completed the focus group last because it was last data source, chronologically, and was ordered as such in my data file organization.

During line-by-line coding, I began organizing codes that seemed similar. I determined how similar the codes were by examining the contexts surrounding the code, meaning I looked at what was happening in the lab by reviewing my own observation notes and any analytic memos that related to the code. These were considered potential categories. The potential categories that began to emerge included *differentiating instruction, student interaction, reducing student anxiety, intentional scaffolds,* and *relevant to students' lives.* Table 3.5 contains examples of codes generated during line-by-line coding. Appendix D contains my code book.

Table 3.5

Sample Line-by-Line Coding and Potential Category Development for Research Question 1

Potential Category	Code generated during Line-by-Line coding
Student Interaction	Ensured multiple students had opportunities to talk Ensuring everyone presented portions of the lab Provided opportunities for students to complete lab work collectively Asked students to talk with each other to determine best answer Challenged students to work together to solve difficult problems
Reduced Student Anxiety	Added class learning objectives for students to see every day Demonstrated challenging lab practices before student trials Demonstrated multiple examples for a particular concept Demonstrating that science can be hard for everyone and that's ok Avoided putting students on the spot
Differentiated Instruction	Incorporated methods for different learning styles in instructions Used multiple modes of displaying information

	Used specific instructional strategy to make sure everyone was on the same page Using an easy assessment technique Used a learning goal as mechanism for student to deepen content understanding
Relevant to Students' Lives	Brought in students' past experiences and knowledge Added prompt for engaging students to relate content to their own lives Drawing on students' interests to build relationships Encouraged students to reflect on their own experiences in relation to content Drawing on students' previous or existing knowledge
Intentional Scaffolds	Added class learning objectives for students to see every day Built on previous week's materials to scaffold understanding Demonstrated multiple examples for a particular concept Edited pre-made slides to include more examples of specific content Ensure content understanding by doing large group check-in

Lastly, I completed axial coding by engaging in constant-comparison methods (Strauss & Corbin, 1998) to explore more deeply the dimensions of my categories. As I engaged in the constant-comparison process, I looked across elements of the categories, such as similarities, differences, and outliers in codes and also asked questions of the data like *what is being said or done?, who is doing it?, why?* (Corbin & Strauss, 2015). In grounded theory, these are called, 'properties' and 'dimensions' of the category, respectively. This is a key part of grounded theory analysis because it allows the researcher to determine which categories to elevate to the level of theme. Theming the data (Saldaña , 2015) occurs by intensively examining the properties and dimensions described above to identify how they relate to their respective category. This lends itself to the development of the interpretive theory or "theories that aim to understand meanings and actions and how people construct them" (Charmaz, 2014, p 228). In this regard, grounded theory is more extensive than other qualitative approaches that conclude with the development of categories (Creswell & Poth, 2018). The resulting themes for Research Question 1 were *Funds of Knowledge Connections*, *Differentiating Instruction*, *Intentional Scaffolding*, and *Reducing Student Anxiety.*

Analyzing Factors that Influenced Teaching Assistants' Ability to Enact Culturally Responsive Science Teaching (RQ2). I engaged in the same analytic procedures for my second research question as I did with Research Question 1. First, I completed open coding by looking across the following data sources: TA reflections, training artifacts such as their weekly writing and brainstorming prompts, and their conversations from the focus group. As with my open coding for Research Question 1, I looked across larger sections of the data in a holistic manner (Charmaz, 2014). To do this, I examined the each of data sources by each TA. Table 3.6 illustrates what open coding and memos looked like for Research Question 2, using Chad as an example. The prompts that Chad was responding to in this table were in relation to her self-report of how she enacted CRST that day (as described in the analysis section for Research Question 1 above) and: *What factors made it easier to teach those strategies? What factors made it more difficult?*

Table 3.6

Example of Open Coding and Analytic Memos for Research Question 2

Date	Reflection Text	Open Codes	Analytic Memos
October 12, 2018	"The lesson was easy to teach because I had done it before several times. I also knew more outside information that previously, so relating to students was simple."	Easy to relate info	"Does TA knowledge impact how they enact CRST?"
November 2, 2018	"I think them knowing me and being cool with me helps me tell them what they need and what	Trusting relationships	"Building trusting relationships is emerging as a critical

	they need to do for the class. I think they trust me and they respect me to do the work that they are required to do without too much grumbling, especially since I agree with them."	aspect of TAs abilities to enact [CRST]"

Next, and like my approach to Research Question 1, I engaged in line-by-line coding of each of the data sources for Research Question 2 in the qualitative analysis software HyperRESEARCH™. Again, I began this process by coding each of the data sources for all TAs. This meant that I examined all TAs' reflections, then analyzed all TAs' weekly writing and brainstorming prompts, and then lastly examined the focus group discussions. Table 3.7 contains examples of codes resulting from line-by-line coding as well as how they were used in initial category development.

Table 3.7

Sample Line-by-Line Coding and Initial Category Development for Research Question 2

Initial Category	Code generated during Line-by-Line coding
Affordances	CRST activities didn't take long to implement
	CRST activities didn't take long to prepare
	CRST activities were straightforward
	Repeating CRST makes it easier each time
	Preplanning helped try new things out
Constraints	Time is limited because labs are jam-packed
	Not having autonomy over the lab makes CRST harder
	Lab design makes CRST difficult
	Hard to balance level of detail and polarized prior knowledge
	Hard to gauge if it's working for students on the spot

Initial categories such as those outlined in Table 3.7 began to emerge. Lastly, I completed axial coding to more deeply explore the dimensions and properties of my categories. As with Research Question 1, I engaged in constant-comparison of the data, exploring similarities and differences in my developing categories. This process allowed me to determine which categories to elevate to the level of theme. The categories in Table 3.7, for example, later became elevated to themes because of the variation across their dimensions. This means I saw similarities in the ways TAs were discussing the aspects of each category which was visible in the frequency with which they discussed those aspects as well as the conditions surrounding them. The resulting themes for Research Question 2 were: *Affordances, Constraints, TA Beliefs about CRST, and TA Identity*.

Theoretical Sampling. Theoretical sampling is a process of identifying and pursuing new leads that have the potential to amplify the development of a theory (Corbin & Strauss, 2015). Theoretical sampling for this study was achieved in multiple ways. First, early initial coding of TA discussions and reflections steered the direction of the weekly training topics, the types of subsequent brainstorming prompts to pursue data sources, and also made clear the need to conducts a secondary analysis of grounded theory findings from a postcolonial perspective. For example, when reviewing the TAs' discussions during our weekly meetings, it became clear that all TAs were concerned about how their teaching decisions influenced their students' ability to have a voice in their own learning. This indicated to me that the TAs were engaging in culturally responsive practices that aimed to promote student agency *and* that were influenced by their beliefs about science teaching. I added discussion and reflection prompts that included student agency as well as asked follow up questions in our post-lab interviews that were aimed at better understanding how their beliefs about science teaching and culturally responsive science teaching influenced their enactment. This later became a significant theme in my findings for my second research question.

Secondly, through initial review and coding of my observations, field notes, and analytic memos, it appeared to me that aspects of identity were part of what influenced TAs to enact – or not enact – CRST. For example, during the weekly training on October 5, 2018, I noted to “review this conversation” in my analytic memos. During that conversation the TAs were discussing that they felt they couldn’t separate aspects of their identity from their own funds of knowledge. I then sought out the council of one of my committee members with expertise in this area, who shared with me research on how the mobility and intersections of identities has been studied in relation to social justice teaching (e.g., Hackman, 2005). From that, I adapted a “Social Identity Wheel” (Program on Intergroup Relations and the Spectrum Center, University of Michigan) (Figure 3.3) that each TA completed privately and were subsequently asked identity-related questions in their brainstorming prompts. Dimensions of how identity factored into their enactment of CRST also later became a significant theme in my findings.

Reflect on these aspects of identity:
Put an x in the corresponding boxes

Identity	**Identities you think about most**	**Identities you think about least**	**Identities that have a strong effect on how your perceive yourself**	**Identities that impact your science learning**	**Identities that impact your science teaching**
Race					
Ethnicity					
Religious or Spiritual Affiliation					
Socio-economic status					
Gender					
Sex					
Age					
Sexual Orientation					
Academic					
Professional					
Family					
Friends					
Other:					
Other:					
Other:					

Figure 3.3 Social identity profile completed by each teaching assistant.

These two examples of theoretical sampling demonstrate the rigor with which I executed the critical process in grounded theory of identifying and following new leads. It also speaks to the ways in which I achieved theoretical saturation, the point where data analysis no longer yields new insights (Charmaz, 2014; Corbin & Strauss, 2015).

Postcolonial Analysis and Critique. Postcolonial analysis is an emerging and dynamic framework that aims to delve more deeply into the ways that colonial legacies manifest in actions, processes, and structures today (Ashcroft, Griffiths & Tiffin, 1995;

Bhabha, 1994; Fanon, 1961; Said, 1978). While there aren't static boundaries for how this critique should be actualized in research, several scholars have paved the way for postcolonial analysis to function as a *re-read* (Bang et al., 2012; Carter, 2004; 2006), or secondary look, of research findings. Table 3.8 captures two domains of postcolonial critique that have been addressed by scholars in Western canonical science and science education. I used this as an analytic framework for my postcolonial re-read, in which I applied each of the major dimensions of those domains to my key findings from Research Questions 1 and 2.

Table 3.8

Analytic Framework for Postcolonial Critique

Domain	Dimensions	Questions
Settled Assumptions	Unitary Assumptions of Teaching and Learning	Do students have to "concede to epistemic control and cultural dominance of the science curriculum?" (Bang et al., 2012, p. 311 Does the curriculum present "assumptions bound to stable and unitary ideas of nation, culture, identity, comparison, and difference?" (Carter, 2006, p. 681)
	Essentialized Assumptions of Phenomena	Are there assumptions of phenomena related to life that are taken-for-granted as essential knowledge? (Bang et al., 2012) Do these assumptions exist in the curriculum? The content? The expectations of TAs' pedagogical approach?
Bounded Knowledge	Binary Knowledge	Are there opportunities to disrupt the binary and bounded knowledge that work to guarantee the

		separation, differentiation, and regulation between the "social sphere, between nature and culture, and between the scientific and unscientific?" (Carter, 2006, p. 683) Where does bounded knowledge "mute" recursive conceptualizations of phenomena? (Bang et al., 2012)
	Legitimization/Delegitimization of Knowledge	Where are there settled expectations of legitimate knowledge? (Medin & Bang, 2014)
	Settled Knowledge-Power Relations	How do settled knowledge-power relations create exclusionary and hierarchical frames? (Medin & Bang, 2014) Where are there spaces to change the settled conditions of science learning? (Bang et al., 2012; Carter 2004; 2006)

Researcher's Role & Positionality

Researcher's role. Prior to beginning my doctoral work at the University of Minnesota, I taught undergraduate science courses at a Tribal College in Northern Minnesota. Among the subjects I routinely taught were General Biology, Environmental Science, and Ecology. Through my own process of developing and growing as an educator, I became well-versed in the struggles that novice teachers face in the science classroom. Additionally, I became acutely attuned to the barriers Native American students work to overcome in science learning environments. These aspects of my professional expertise, coupled with my emerging expertise in culturally responsive science teaching, positioned me to be an effective and responsive leader to my teaching assistant participants. As their instructor and mentor, my role was to facilitate their learning of culturally responsive science teaching as well as support them as they engaged with the concepts of, and enacted, CRST.

Positionality. In recent studies, positionality and reflexivity are prominent themes within which educational researchers seek to better understand issues of representation in qualitative approaches (Macbeth, 2001). As this study aims to contribute to my field in novel ways, addressing my positionality as a researcher is vital to assuring that my representation of findings is accurate. My positionality as a researcher, though ever-evolving, is grounded in three domains: my Native American heritage, my identity as what I call a "science person," and being a woman in the sciences. These identities are what draw me constantly to the critical domains in qualitative research and keep me focused on the postcolonial aspirations of desettling (Bang et al., 2012) and disrupting colonial legacies in science and in the academy.

My grandfather is a Tribal member of the White Earth Band of Ojibwe and I am an Anishininaabe descendent. I have spent over ten years working within Anishinaabe communities in Minnesota, and strongly value the Seven Grandfather Teachings: *Gwayakwaadiziwin* (Honesty), *Debwewin* (Truth), *Inendizowin* (Humility), *Zaagi'idiwin* (Love), *Nibwaakaawin* (Wisdom), *Zoongide'iwin* (Courage), *Manaaji'idiwin* (Respect). The collective epistemic violence that we face as Indigenous people is always at the forefront of my mind. This is particularly prominent in Western science disciplines where Indigenous knowledge is devalued and excluded. These realities drive my research interests and how I approach the scholarship of teaching and learning.

I refer to myself as a "science person" as a way to encompass all of the traits of my scientist identity. While I am trained in the traditional skills of critical thinking, inquiry, and analysis, I refuse to accept societal perceptions of scientists that relegate us to lab coats and beakers or classify us as “geeks” or “nerds.” I’ve always viewed the propensity to wonder as a foundation of science and I perpetually work to advocate that there many different ways to wonder, and, therefore, a myriad of ways in which we can know things. This is particularly important in relation to research with populations that are oppressed within typical Western views of science.

Lastly, as a woman and first-generation college student in the sciences, I am constantly fighting to affirm my validity. When I was working on my master’s degree in Environmental Science, I was one of only a few female students and all of my professors were male. My male classmates, though likely unintentionally, consistently minimized my voice, especially in the more concrete domains of science (as opposed to environmental policy, for example). Likewise, when I began working as a science instructor at a Tribal College, I was the only woman in the department. There, the intentions to quiet my opinions were very obvious, despite the fact that my credentials outranked those of all of my department colleagues. As a first-generation student, my pathway to the Ph.D. has been both turbulent and lonely. First-generation college students often lack a support system because our families can’t relate the level of stress and commitment associated with higher education. Furthermore, as a first-generation student, imposter syndrome – the feeling that one isn’t good enough or smart enough even when they are the most qualified in the room – is buzzing in the background of my mind nearly every hour of the day. In a male-dominated, highly competitive field where often times the loudest voice in the room is what is value, my status as female and first-generation play a significant role in the way I conduct myself. These experiences have shaped me into a fierce advocate for equity and social justice in science and science education and particularly so for Native American students who are already marginalized in the field.

Reflexivity, attention to researcher positionality, and connecting with participants are each important aspects of critical epistemologies in research (Barton, 2001) and it is imperative to maintain those connections throughout the analysis process.

Trustworthiness

Charmaz (2014) describes the process of achieving trustworthiness in grounded theory research as a multifaceted. While this varies from study to study, general guidelines include credibility, originality, resonance, and usefulness.

Throughout my data collection period, I achieved credibility by consistently reviewing these questions outlined by Charmaz (2014): *Are the data significant to merit your claims* (considering range, number, and depth of observations)?, *Have you made systematic comparisons between observations and between categories?*, and *Do the categories cover a wide range of empirical observations*? (p. 337). As described in my data sources section, my collection timeline and process allowed me to build a rich repository of information. This triangulation of data sources made it possible for me to complete the in-depth constant-comparisons (Strauss & Corbin, 1998) necessary to build categories to themes and achieve theoretical saturation, both critical and defining aspects of grounded theory (Corbin & Strauss, 2015).

In order to address the issue of originality, I kept an ongoing list in my researcher notes to review the "social and theoretical significance" of my emerging themes (Charmaz, 2014, p. 337). I added statements or questions each week that interrogated the meaning of the things I was seeing. This also served as a resource for me when I was reviewing my analytic memos.

Achieving, or seeking to achieve, resonance in grounded theory can be described as a process of 1) examining how your data and emerging categories and themes reflect the depth and breadth of the experiences of your participants, 2) assuring your grounded theory is both clear and coherent, and 3) asking whether or not your findings and work tell deep and meaningful story that can be compared or linked to other individuals and institutions (Charmaz, 2014). I achieved resonance by examining my data on a micro and macro level. Engaging in line-by-line coding, as described earlier in this chapter, offered in-depth insights about what my participants were doing and experiencing. Those line-by-line codes became integral to comparing the properties and dimensions of each category, which also helped me to achieve resonance.

Lastly, I examined matters of usefulness by reviewing how my analysis and findings lend themselves to future research and discussion. I did this by consistently looking for big-picture connections and if my work contributed to the knowledge in my field.

Charmaz (2014) contends that "a strong combination of originality and credibility increases resonance, usefulness, and the subsequent value of the contribution" (p. 338). My data sources and analysis reflect rigor in each of these criteria.

Chapter 4: Findings

This chapter presents the findings of this grounded theory study which aimed to understand the processes of enacting culturally responsive science teaching (CRST) in undergraduate biology instruction and the factors that influenced teaching assistants' decisions whether or not to implement CRST. Additionally, I sought to uncover and critique colonial structures in Western canonical science and science education. The research questions guiding this study were *1) In what ways do biology teaching assistants enact culturally responsive science teaching?* and *2) What factors do biology TAs share that influence their decisions to enact culturally responsive science teaching?*

This chapter is divided into three sections. The first two sections discuss findings for each of the research questions and the third reviews the findings from a postcolonial perspective. In presenting the findings for my first research question, I describe four themes that emerged from the data: *Funds of Knowledge Connections*, *Differentiating Instruction*, *Intentional Scaffolding*, and *Reducing Student Anxiety*. The dimensions of each theme are further explored in sub-sections. The findings for my second research question are also presented according to the major themes that emerged from the data: *Affordances* and *Constraints* of engaging in culturally responsive science teaching, *Beliefs about CRST*, and *TA Identity.* The corresponding properties and dimensions of those themes are further explored in sub-sections. Lastly, the major findings from my postcolonial critique are presented from two salient vantage points in postcolonial theory: *Settled Assumptions* and *Bounded Knowledge*.

Research Question 1: In what ways do biology teaching assistants enact culturally responsive science teaching?

In this section, I present the ways in which each of the teaching assistant (TA) participants enacted culturally responsive science teaching throughout the semester. After a brief overview of the general trends I saw for TAs enacting each of the themes, I first describe how TAs utilized *Funds of Knowledge Connections* in various ways that reflect culturally responsive instruction. Secondly, I illustrate the actions TAs took to *Differentiate Instruction* and how those actions were student-centered. Next, I describe the *Intentional Scaffolding* TAs incorporated as part of their culturally responsive science teaching. Lastly, I describe how TAs intentionally engaged in *Reducing Student Anxiety*.

Overview of TA Enactment Frequencies. The TAs enacted culturally responsive science teaching in several ways which are illustrated in Figure 4.1 at the elevated level of *theme*. As previously discussed in Chapter 3, the term *theme* refers to the product of grounded theory analysis wherein individual codes and categories are intentionally reconstructed and elevated to reflect an abstract conceptualization of processes and actions of the participants (Charmaz, 2006). The themes below, *Funds of Knowledge, Differentiated Instruction, Intentional Scaffolding,* and *Reducing Student Anxiety*, each consist of several categories which describe the properties and the dimensions of the theme.

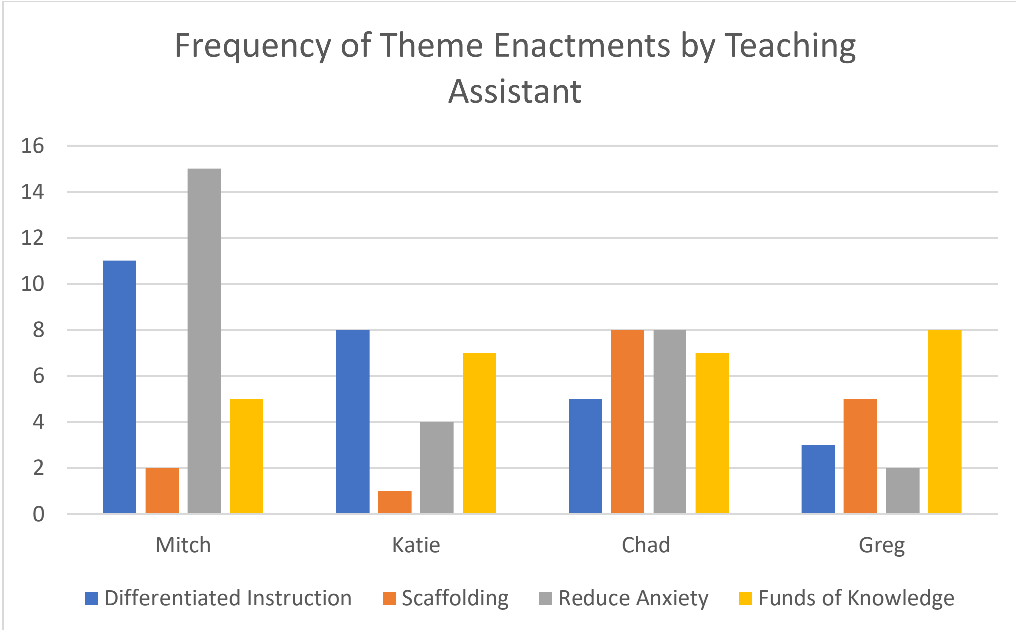

Figure 4.1 Frequency distribution of enactments related to each theme across all teaching assistants.

Figure 4.1 illustrates that each TA enacted CRST through all four themes, and that they enacted each of the themes to varying degrees. The frequency of theme enactments refers to the number of times throughout my data analysis process that each TA engaged in an aspect of CRST that could be described by that theme.

Funds of Knowledge Connections. As described in Chapter 2, funds of knowledge connections in culturally responsive science teaching refer to the ways in which educators make deliberate links between science content and processes and students' funds of knowledge – the skills, talents, and household knowledges and practices accumulated over time and within their homes and communities (González, Moll, & Amanti, 2006; Moll & Diaz, 1987; Vélez-Ibáñez & Greenberg, 1992). Funds of knowledge (FoK) connections emerged as a salient theme in exploring the ways TAs enacted culturally responsive science teaching. Not only was the theme of FoK connections prevalent for TAs as they engaged in CRST, it was the most consistently enacted theme across all TAs (Figure 4.1). Funds of knowledge connections are described below according to their dimensions and properties. In this study, the categories – framed as sub-headings – were the dimensional aspects of the theme. These dimensions included *funds of knowledge to solve a problem*, *using funds of knowledge to build student confidence*, and *using funds of knowledge to make science content and processes more relatable*. The sub-sections below describe the properties of each category in the *Funds of Knowledge Connections* theme.

Funds of Knowledge to Solve a Problem. Mitch, who has displayed the most depth and breadth of enacting culturally responsive science teaching as evidenced by the highest number of observed CRST enactments, consistently provided opportunities for students to bring in their funds of knowledge. One of the central components to Mitch's lab was that students engaged in a CURE (Course-based Undergraduate Research Experience) for the duration of the semester in addition to other weekly lab activities. The overall CURE experiment for these students was predetermined by the BE faculty to build on an existing database of research that measures increases/decreases in the Zone of Inhibition – an area in a petri dish that can be used to determine how susceptible a bacterium is to antibiotics – by testing a variety of perishable items of the students' choosing. Mitch encouraged students to bring in their past experiences and household knowledges by asking them to think about their CURE work in relation to their own lives. In introducing the CURE and when explaining that the students had some autonomy to choose their own test items, Mitch asked "does your family – or your household or friends – do anything specific to keep food from spoiling?" (Weekly observation, October 12, 2018). This generated a lot of discussion among students about what kinds of foods they knew to grow moldy quickly versus others that seemed to last "for ages" in the refrigerator and the possible reasons. For example, the following summarizes an exchange that happened across two groups with different experimental variables, lemon juice and apple cider vinegar:

> *Student from the lemon juice group said that they chose it because "Cassie's [pseudonym] mom always puts it on apples to keep them from getting brown." Others from the group then talk about how they think there might be a connection between something in the lemon juice properties and amount of bacterial activity. The apple cider vinegar group is at the same lab bench and adds that they chose theirs for similar reasons – that there might be a relationship between the properties and the frequency of bacterial growth. Then another student from that group also says "but remember then Anton said his grandma took like two tablespoons a day and never had a single stomachache?" and the two groups keep talking about how apple cider vinegar is a current diet trend too.* (Observation field notes, October 12, 2018).

This demonstrates how Mitch created a space for his students to share information with one another and then build on that knowledge in the lab activity. In similar ways, Greg couched household knowledge or lived experiences in problem solving to get students thinking about how they might study termite behavior, a lab which focused on building students' ability to create and carry out an experiment with appropriate independent and dependent variables and controls:

> "*This week, I tried to get the students to reflect on their own experiences as problem solvers by getting them to write about a problem they had to solve and talk about how they solved it. In addition, because we talked about how termites get home, I started off the discussion with how themselves would get home as a starting point."* (Weekly reflection, October 19, 2018).

Greg's reflection indicates that he was attempting to elicit students' FoK with specific respect to problem solving and as a way for them to build on those funds in the lab activities.

Using funds of knowledge to build student confidence. In addition to eliciting students' funds of knowledge as a way to solve scientifically-driven problems, the TAs also drew upon their students' funds to cultivate confidence. Mitch, for instance, continued to engage in funds of knowledge connections as a way to build student confidence in their lab research. He reflected,

> "*I had some really good conversations with students about what materials they brought from home for their CURE. I was most excited when talking to a student who hadn't spoken at all to me yet this semester, because she felt responsible for one of the materials. It gave her some authority in the lab which I think made her more confident."* (Weekly reflection, October 26, 2018).

He described this process of apply FoK to specific problems as both a way for students to feel more confident and comfortable as researchers in the lab as well as to build rapport with them as the teacher, which he said "makes the learning process more comfortable" (Post-lab interview, October 26, 2018). Mitch repeatedly expressed time as a limiting factor in his abilities to try all the CRST strategies that he wanted to try, citing that "one-on-one conversations take time to actually be rewarding" (Weekly reflection, October 12, 2018) but that FoK connections tend to catalyze the process of building trusting relationships with students (post-lab interview, October 26, 2018).

Katie also drew upon students' FoK as a tool to build their confidence throughout the semester. Early in the year, and then periodically thereafter, Katie did a writing exercise (a three-minute paper) with students where she prompted them to reflect on what they knew about a given topic. This occurred at or near the end of the lab period, which she also used as an opportunity for students to share out and debrief about the lab material for that period. She referred to these writing exercises as them adding to their "knowledge bank" and used their responses to guide her instruction. For example, one week it became evident to Katie upon reading students' reflections that many had some procedural confusion about their lab work. From there, she added logistics and checklist slides (Figures 4.2 and 4.3) every week.

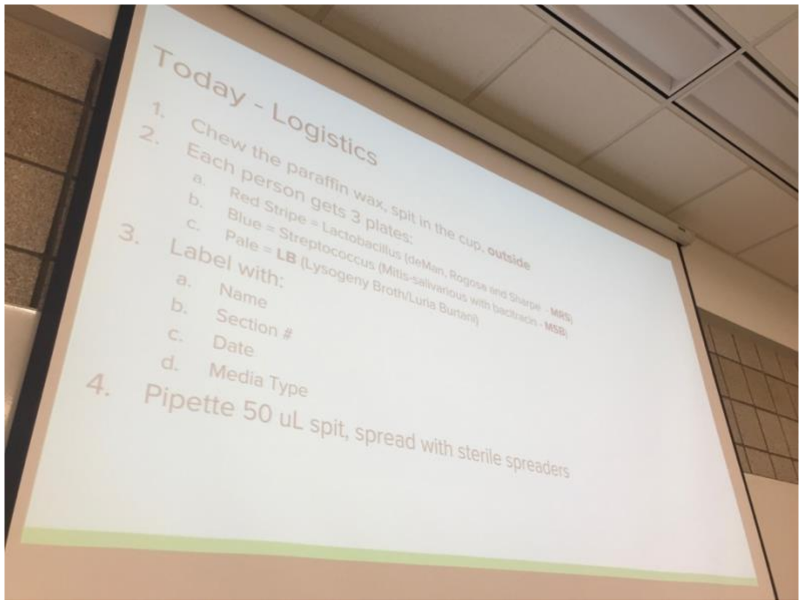

Figure 4.2 Katie's additional logistics slide.

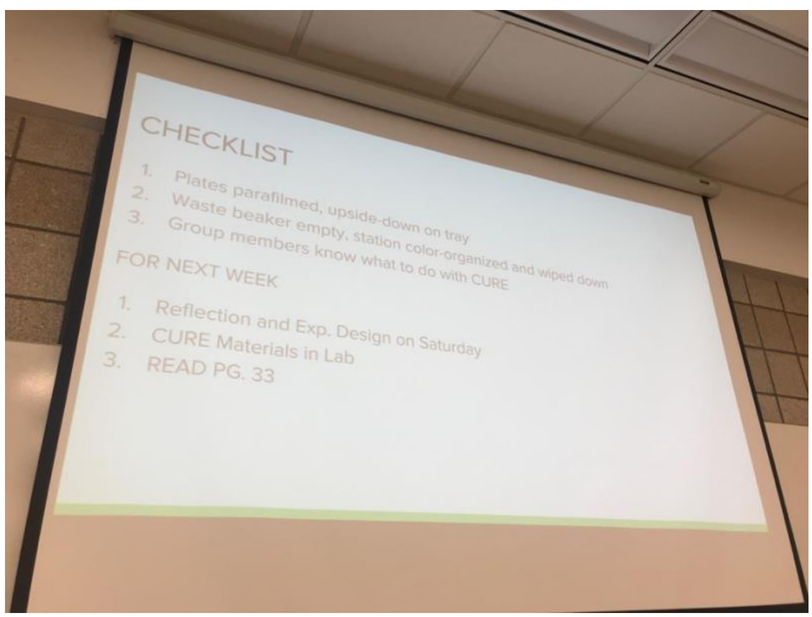

Figure 4.3 Katie's additional checklist slide.

Katie added a slide for what she called "logistics" (Figure 4.2) which reiterated to the students lab instructions that were important for maintaining precision throughout the activity. She also built in a check-list (Figure 4.3) for students to be able to reference easily while they were working. Additionally, Katie commented that "having students draw on their previous knowledge of the material gave them more confidence since it proved to themselves that they already know important stuff" (Post-lab interview, September 28, 2018).

Chad demonstrated a different way that providing opportunities for FoK connections could build student confidence. While working with her students on a lab wherein they were identifying how blood clots (as well as genetic factors that influence coagulation), Chad circulated among students and asked each group if they wanted to share any knowledge they had of a family history of blood clotting issues. Some shared that they had a family member on blood thinners because of high risk of stroke and that opened conversations across the room about how common of an issue it was. In this space, Chad created an atmosphere that, by sharing personal and family experiences with a health issue, students both appeared comfortable and more at ease in applying the content of the lab to their daily lives. Later that day, I overheard one pair of students commenting about being enrolled in Chad's lab, "I love this lab so much – I'm so glad I signed up for this section" (Weekly observation, September 27, 2018).

Using funds of knowledge to make science content and processes relatable. Another dimension of how TAs enacted CRST through funds of knowledge emerged as mechanisms by which to make science – both content and process – relatable to students. For example, Mitch's students were responsible to create a public service announcement

(PSA) as a science communication skill-building exercise. The PSA was related to their CURE experiments, which meant it was personalized information tailored to each group as they each chose their own experimental variables from household products. The assignment, as outlined for the course, was to create a PSA (which counted for approximately 2 percent of their total lab grade) and took place toward the end of the semester-long CURE project. Mitch took the instructions and expectations to a deeper level. To the students, he said:

> "*Aim higher" --- look at a case study of why your research might matter – using primary literature or some other sort of reliable evidence, find a community that has a health disparity that would benefit from a public health intervention based on your research. The scale is up to you: [it] could be all of the dentists in America, a country, a town, a community that has need of or could benefit from your research in a passionate and creative way – you are an outsider, not presenting as though you know everything. Do you see how this will lead us to have a more fruitful conversation? And this is the best example of why we do science*." (Weekly observation, November 15, 2018).

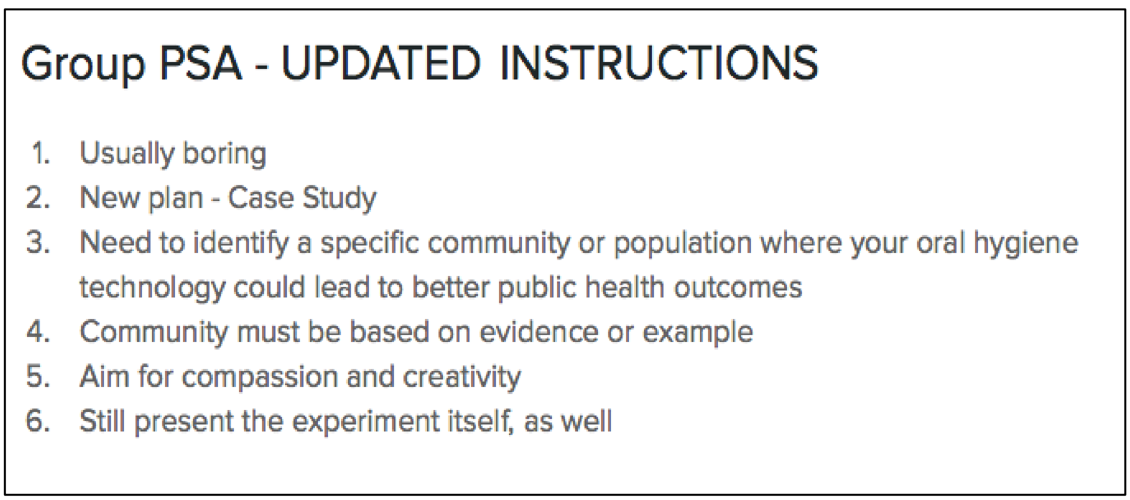

Figure 4.4 Instruction slide for PSA in Mitch's lab (November 15, 2018).

Figure 4.4 illustrates the updated instructions Mitch created for the PSA assignment wherein he added the expectation to build the PSA around a case study. He highlighted in step one that students usually found PSAs to be boring and that he also felt that students tended to be bored with them. Without changing the rigor of the assignment, Mitch changed the expected outcome of the PSA to be a case study that focused on communities and on effectively communicating science in ways that students could draw on their own knowledge and creativity.

On a closing note related to this theme, throughout the semester, none of the TAs expressed discomfort or feelings of awkwardness surrounding utilizing students' funds of knowledge in their teaching. In fact, several times TAs cited the repetition of trying new strategy for culturally responsive science teaching as a confidence building mechanism for them "having done it before made it less awkward to implement [intentional scaffolds] again" (Greg, weekly reflection, October 4, 2018).

There was also an element of self-improvement visible across TAs in this theme. Greg, who was the most likely to offload strategies or ideas of culturally responsive science teaching directly into his instruction, identified on several occasions how he improved a funds of knowledge connection from one week to the next. For example, one of the ways Greg elicited students' funds of knowledge was by prompting them to draw on their own relevant experiences to make specific and meaningful connections to the content. He reflected,

> "*The first time I did this, I ended class with a reflection and discussion about how the students could use the concept of that day in their own lives – we were talking about identifying reliable data. Then I improved on it to broaden the topic and my prompt became how they could relate to science as a whole*," (Weekly reflection, October 4, 2018).

Differentiating Instruction. The theme of differentiating instruction encompasses two major dimensions, *accommodating and anticipating students' needs* and *building positive and safe science learning environments*. The name of the theme refers to the fact that within each of the major dimensions, the TAs were changing their instructional methods – or differentiated instruction – as a result of some aspect of an observed student need. As culturally responsive science teaching includes pedagogies that are "asset-based, foregrounding students' learning potentials instead of emphasizing their perceived deficits" (Brown & Crippen, 2017, p. 101), differentiating instruction to meet students' learning needs is inherently a culturally responsive practice.

Across all four TAs, I observed multiple ways in which they differentiated instruction over the course of the semester. The following sub-sections illustrate those examples by exploring the dimensions of this theme: *accommodating and anticipating student needs* and *building positive and safe science learning environments* and how they lead to differentiating instruction.

Accommodating and Anticipating Student Needs. The process of a teacher changing one's practice intentionally to better serve their students is a culturally responsive practice as it assumes a student-centered approach motivated by a desire to improve student self-efficacy and learning (Ladson-Billings, 1994). Chad is a shining example of how a TA can engage in both the process of being accommodating to students as needs arise as well as being able to anticipate those needs. In nearly every observation (9 out of 10 observations), Chad would circulate the room as students worked in pairs or groups and ask each student pointed questions about what they were doing and why they were doing it. She often engaged students in that kind of metacognitive reflection as a way to gauge whether and how much she might need to differentiate her instruction to meet student needs. For example, during a lab where students were tasked to identify blood types and antigens, Chad quickly learned that several students were struggling with the concept of how blood type and antigens were related. She paused the lab to use various visuals – such as videos, sketches, and additional images – to further demonstrate what she had previously lectured about in a slide. Of this pedagogical decision, Chad shared, “I tried to incorporate different learning styles – both visual and auditory – at that point because after asking them why they were doing the [experiment], many of them couldn’t answer” (Post-lab interview, September, 28, 2018). Figure 4.5 demonstrates such an instance where Chad added an additional slide to elicit student discussion through peer interaction, which was an extra step Chad added to the lab curriculum. Atwater, Freeman, Butler, and Draper-Morris (2010) contend that accommodating students by differentiating instruction and anticipating student needs is a necessary component of practicing culturally responsive science teaching.

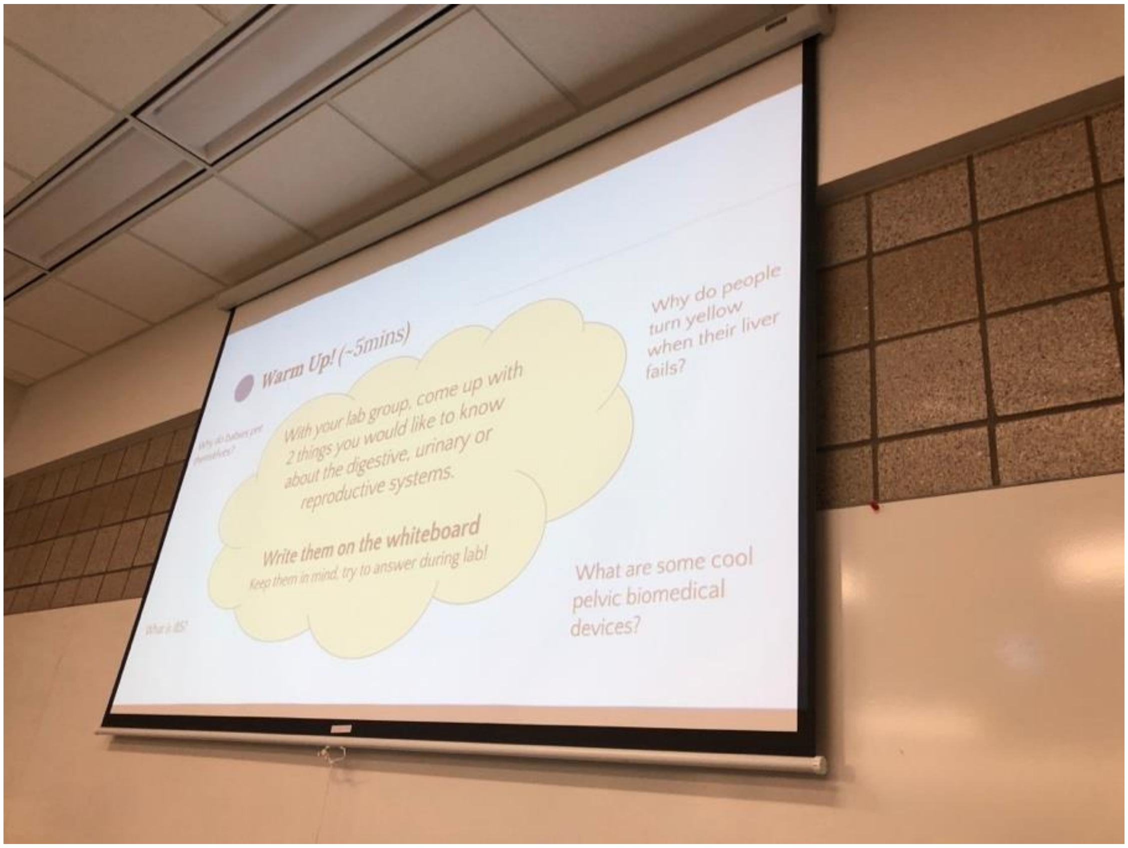

Figure 4.5 Example of how Chad incorporated differentiated instruction in her lab.

Likewise, Mitch consistently used learning goals as a way to deepen students' understanding. Learning goals – especially if utilized as a precursory slide to a lecture or instruction – can be powerful tools as adult learners can more easily retrieve information if they have a framework or goal associated with it (Bransford et al., 2000). Basu et al. (2007) contend that creating opportunities such as this is a critical aspect of equitable instruction. Mitch described his process of using learning goals as a specific tool for being able to better identify where students may need additional supports and/or differentiated instruction.

> *"I did a learning goal exercise which first asked them to share their opinions and knowledges on evolution. There was a wide range of responses, with some very suspicious of evolution or at least human evolution. Then we discussed*

> *[evolution] in relation to what the learning goals were for the lab. I felt like it was really helpful."* (Post-lab interview, November 9, 2018).

Here, Mitch utilized the learning goal activity as a way to accommodate students' needs in learning human evolution, citing it proved to be helpful. After the discussion, Mitch added some think-pair-share and group discussion prompts that he hadn't previously planned for as a way to make the evolution concepts more digestible, citing that because the content for the day was quite "intense" he felt students fared better in their understanding if he broke it up is smaller pieces to discuss (Post-lab interview, November 9, 2018).

Katie also adjusted her instructional techniques throughout the semester to meet the needs of her students. Though these adjustments were made in advance and also in-the-moment, they were consistently based on information learned about her students. In one particular instance during a lab about starch enzymes and hydrolysis, a student asked Katie about the process of hydrolysis. While the question was relevant to the experiment, the basis of the question was wrong. Katie responded, "That's a good question and very intuitive that you would think about it in that way" (Weekly observation, September 25, 2018). Realizing that the student needed a different explanation for the phenomenon, Katie drew what she referred to as the "PacMan Diagram" to illustrate how enzymes work (Figure 4.6). The following week, she re-created her drawing in another visual that she incorporated in her slides. Similar to Mitch's reasoning for breaking content into smaller pieces, Katie explained that the PacMan diagram was a way to offer students' another view of the information, saying that "students would feel more confident in their learning" if they had multiple vantage points from which to access information (Post-lab interview, September 25, 2018).

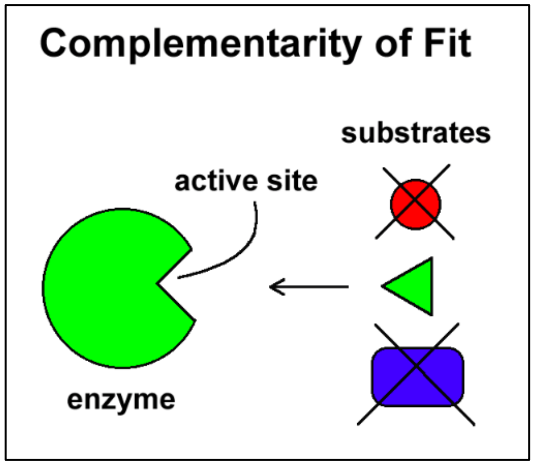

Figure 4.6 Katie's "PacMan" diagram.

Lastly, each of the TAs practiced interactive lecturing throughout the semester. Interactive lecturing was a time used by each TA to accommodate and anticipate their students' needs. This was evident most often by their use of the following active learning techniques: Multiple Hands, Multiple Voices (where the TA poses a question and asks for three to five hands raised before anyone answers, once the hands are in the air, TA calls on each person to answer the question), Think-Pair-Share (TA gives students a prompt and ask them to think individually about it, then discuss their thoughts with a partners, and then share out to the entire group), and Minute Papers (TA prompts students with a question or two and gives out notecards; students have one, two, or three minutes (TA preference) to write their answers or reflections (Tanner, 2013). Ladson-Billings (2014) described traditional classroom structures as disenfranchising students and particularly students of color. The TAs engaged students in these varied, interactive lecturing practices because they felt it reached more students' learning styles (Focus group discussion, December 7, 2018). By doing so, the TAs were changing the structure of the classroom and thereby practicing elements of CRST.

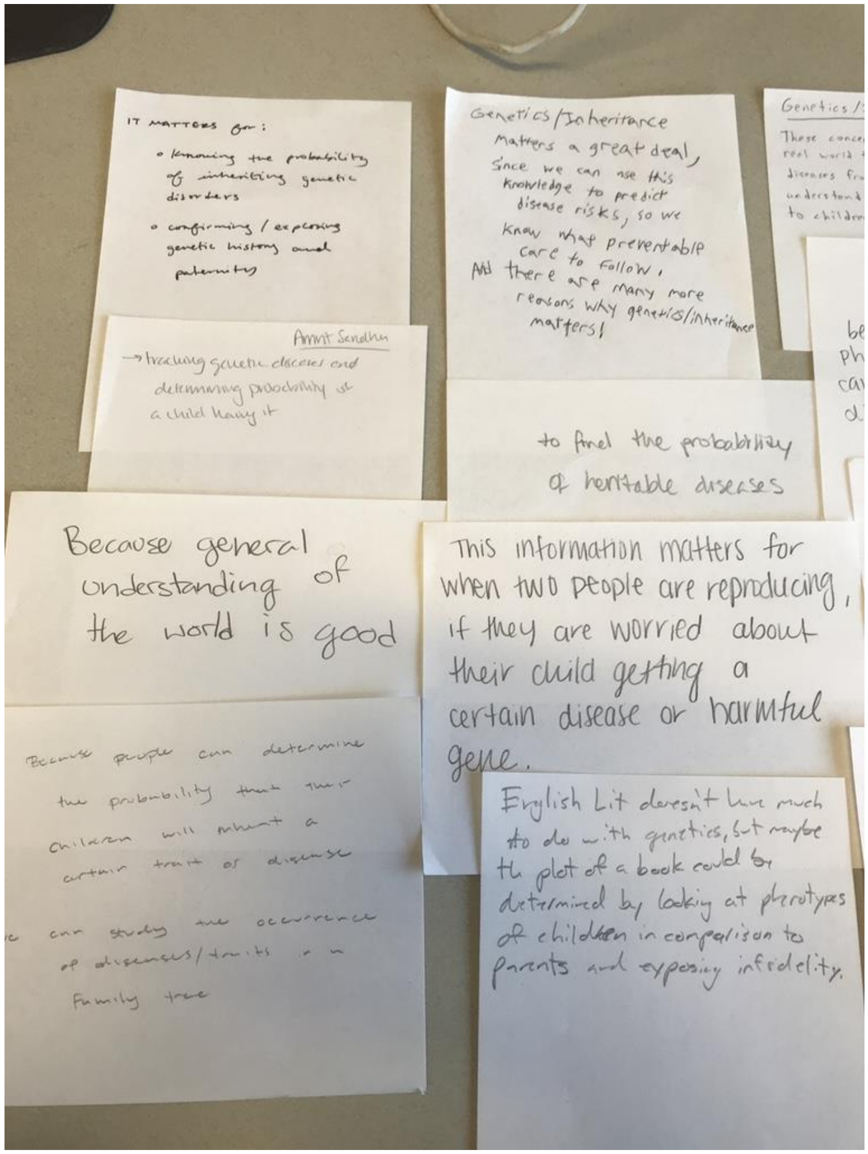

Figure 4.7 Minute paper responses to Greg's prompt, "how is Mendelian genetics relevant to our lives outside this lab?" (Weekly observation, September 27, 2018).

Building Positive and Safe Science Learning Environments. As described earlier in this chapter, differentiated instruction is the process of intentional altering instructional practices and these TAs were doing so because they perceived various aspects of student need. Gay (2010) contended that building positive and safe science learning environments was an important part of culturally responsive science teaching. The TAs demonstrated this aspect of CRST in several ways. For example, they demonstrated differentiated instruction for the purpose of creating a positive environment by using specific or varied teaching strategies to make sure all students had fairly similar levels of content understanding – or were “on the same page” – of the content. Mitch, for example, structured debriefing conversations at either the end of his lab or at the conclusion of a major concept. He described this as an “intentional effort to engage students to provide [him] with a way to see where students’ misconceptions might be as well as provide students with a space to understand the content without having to admit if they were wrong” (Post-lab interview, September 28, 2018). Likewise, Mitch used as many opportunities to use personal examples in his instruction as a way to “make students see science as more approachable and see me as approachable and human” (Weekly reflection, October 19, 2018). In these examples, Mitch’s connections to culturally responsive science teaching are evident in three ways: he made an intentional effort to encourage collaborative learning and connections among students, he sought to better gauge student understanding to explicitly validate his students’ knowledge, and he demonstrated microlevel culturally responsive knowledge (Brown & Crippen, 2017) of effective student-educator relationships.

Greg created safe science learning spaces in similar ways. During a week where students were learning about bacteria and antibiotic resistance, he weaved in personal and family experiences with antibiotics as a way to invite his students to do the same. While students shared some stories about family members who were sick and had developed infections that were difficult to treat (e.g., Methicillin-resistant Staphylococcus aureus, MRSA), Greg wrote down some shared experienced on the board and drew upon them as common aspects of science learning. In my field notes, I recorded:

> *"Greg writes down on the board as students share what experiences they have had with antibiotic-resistant infections. He created a t-chart of the events students described by placing the illness/infection on one side and then filled in some common antibiotics on the other side. As he does this he says "now what have we learned so far about these kinds of antibiotics?" and students responses vary – some say they are gram positive or gram negative. And then he asked students what aspects of bacterial infections they most remember and understand. Lots reply that the ones like MRSA because they had a scary experience. Then Greg says "you will be more likely to remember science stuff if you can make a personal connection to it – maybe we can do this with other things – would that be helpful?" and students nodded and responded yes"* (Observation field notes, October 12, 2018).

He later explained that by making his lecture interactive and discussion-based, it illuminated for students that they already have science knowledge and that the material didn't need to be "scary" which was particularly important for making personal connections to other science topics later in the semester (Post-lab interview, October 12, 2018).

Chad displayed a particularly innovative pedagogical approach to building a positive and safe learning environment. While engaging students in a lecture about the anatomy and physiology of the human heart, she danced and acted out what the heart would look like at various rhythms and connected that movement to a dance analogy. "Your heart is like a conductor, but it can't beat uncoordinated" (Weekly observation, October 11, 2018).

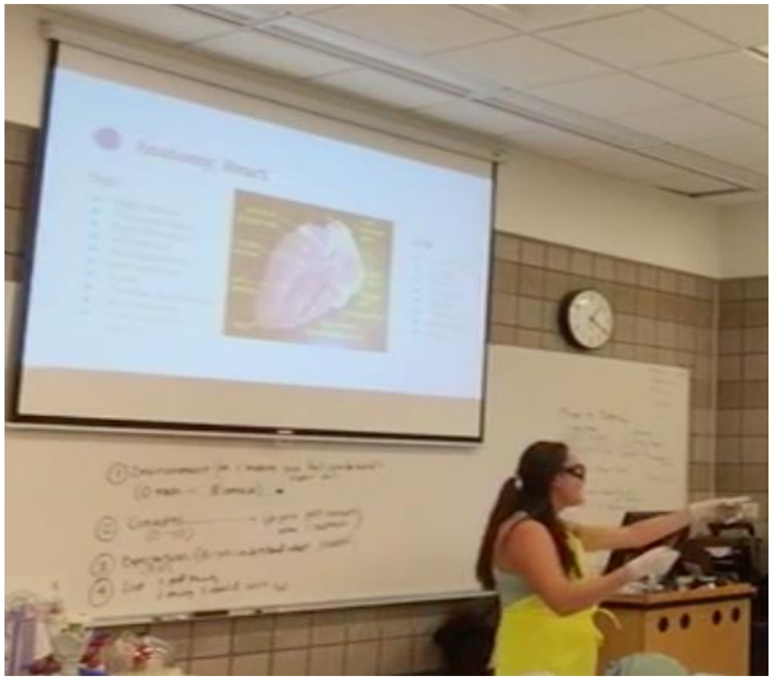

Figure 4.8 Chad building positive learning environments by differentiating her instruction during the heart anatomy and physiology lab.

In this activity, Chad changed the traditional structure of her learning environment by demonstrating to students in novel ways how they could remember heart rhythms. Ladson-Billings (2014) contends that typical classroom structures can, by nature, be disenfranchising to students, yet here Chad clearly disrupted such a typical structure.

Intentional Scaffolding. The theme intentional scaffolding refers to processes that TAs engaged in to explicitly build scaffolds that would aid in students' science learning experiences. Scaffolding refers to an action or support provided by the teacher that aids in learners' abilities to develop understanding or comprehension (Hammond & Gibbon, 2005; Vygotksy, 1978). Providing science learners with intentional scaffolds can build confidence in science understanding, therefore encouraging student agency in science learning (Calabrese Barton & Tan, 2009). Each TA utilized intentional scaffolding as an enactment of culturally responsive science teaching in two ways: to *reinforce knowledge and build learner agency* and to *connect a concept to a bigger picture topic*. These dimensions and their related properties are further described below.

Scaffolding to reinforce knowledge and build learner agency. One of the challenges faced by the TAs whom I worked with is that they lacked autonomy with respect to the content and structure of the labs they taught. As core non-majors biology courses, these aspects were designed and decided by the faculty. For this reason, the fact that the TAs applied scaffolding opportunities in a variety of ways.

Chad, for example, took the liberty of adding extra instructions at various time points throughout each lab, citing that "lab procedures should be scaffolded just like content should be scaffolded" (Post-observation interview, October 18, 2018). For example, the unedited curriculum contained procedural instructions as outlined in the lab manual, but Chad added instructions in her slides that connected students' procedural knowledge about general lab decorum and activities. Some additions included the phrases "this is similar to what we did last week only now we add two steps" and "we've already practiced this before, now we're going to apply this to a different scenario" (Observation field notes, October 18, 2018 and November 1, 2018, respectively). When Chad did this, she was using very little additional instruction time but it gave students opportunities to build on their prior knowledge of lab procedures.

Another approach Chad used to scaffold concepts was to make deliberate explanations for why she chose specific pedagogical techniques. For example, at the end of the lab where she literally danced the rhythms of the human heart, she ended by saying,

> "*I wanted to let you know that I do that for specific reasons: if you can connect that concept to me looking silly and dancing while teaching, you can more easily remember what the lesson was about and then make deeper connections next time we talk more about the circulatory system."* (Weekly observation, October 11, 2018).

In the post-lab interview for that day, Chad explained that making that deliberate connection for her students about content and pedagogy had helped her students in the past feel more confident about how they made connections between concepts. She further explained, "I know I always remembered things better when my teachers explained why they were doing something in that particular way and I think it's because I wasn't initially really a science person, like most of my students" (Post-observation interview, October 11, 2018).

Likewise, Greg took the initiative to add additional slides where he felt it was necessary to build stronger scaffolds between concepts. Firstly, Greg described that he regularly changed the format of the slides he was given to work from because, in his previous experience, the layout was inaccessible to many of his students. Secondly, Greg built on the content in the slide to either make the content clearer or to provide more relevant examples and images to his students. In one such instance, Greg added a slide with additional examples of incomplete dominance because he felt like the "old, stereotypical examples didn't make the idea clear" to his students (Post-lab interview, September 28, 2018) (Figures 4.9, 4.10).

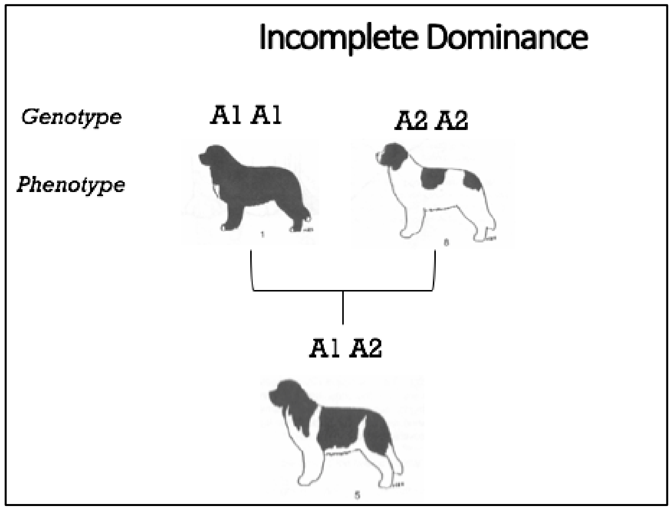

Figure 4.9 Greg's original slide.

Figure 4.10 Greg's additional slide.

Greg then used that scaffolding to engage students in a brainstorming discussion about other example of incomplete dominance they may be able to identify. But providing this intermediary step, Greg set his students up both to succeed in the learning activity in the lab as well as to feel more confident about their science learning and understanding.

Reducing Student Anxiety. The theme of *reducing student anxiety* refers to the ways that TAs utilized CRST practices to aid in the process of easing perceived student anxieties and tensions students may have surrounding science concepts and processes.

Each of the TAs discussed that their efforts to reduce student anxiety were intentional and centered on two specific areas: *using humor to diffuse stress and build community in the lab* and *making science more accessible to students*. These dimensions and their related properties are described further next.

Using humor to diffuse stress and build community. The act of incorporating humor into their instruction was a common dimension of the reducing student anxiety theme. Each TA throughout the semester made mention of the idea that using humor to diffuse stress was important to them as teachers. It is important to point out here that they all commented in one way or another that this is a reaction to a) their past experiences with science teachers who were stoic, boring, and/or ineffective, and b) to combat negative student perceptions of what science looks like.

They ways that Chad utilized this particular strategy are bold and innovative. For example, during a lab where students were measuring the effects of various elements on heartrate (i.e., ice-cold water), Chad started the discussion by sharing a personal anecdote about how she has felt the change in her heart rate when she goes freshwater scuba diving in Lake Superior. One student asked if she wore a scuba diving suit and if having her face only exposed to the cold water would impact her heart rate. Chad responded with, "well what would you hypothesize about that?" and students responded with various answers. Then, a student suggested one of them dunk their face in the cold water they had on hand, to which Chad volunteered. While the entire lab found it hilarious, they were also more engaged in the idea of factors affecting heartrate than they were before.

> "It was an impromptu way to be funny and get them more interested in what we were doing in lab. Measuring heartrate – even with the ice water here – can be

> monotonous sometimes. I like that they felt like it was ok to have fun while exploring something in the lab" (Post-lab interview, October 18, 2018).

Making science accessible. Creating spaces for science learners to be able to see themselves as scientists is a key component of science identity in culturally responsive science teaching (Carlone & Johnson, 2007). Throughout the semester, Mitch consistently reflected that he wanted his students to feel more connected to the process of science and to see that engaging in the enterprise of science didn't need to be insurmountable – that they could be and see themselves as scientists. He brought this to life in his instruction in a variety of ways. First, he made it clear in his weekly planning as well as reflections that he wanted to "encourage group participation and interaction that [didn't] put students on the spot" (Weekly reflection, October 26, 2018). For Mitch, making students feel comfortable discussing science processes and content was equally important to their understanding, because he felt strongly that communication across peers and peer groups "better reflected what science is really about" (Post-lab interview, October 26, 2018). He talked explicitly about how making it clear that it was "okay" to be wrong and to need several attempts to get something right was a completely normal – if not desired – aspect of what science is all about. For example, in one lab that required a very specific and accurate placement of parafilm over petri dishes in order to yield accurate results, Mitch physically demonstrated what the process looked like and then pointed out the places where his placement wasn't accurate. He recounted:

> *"I didn't get it wrong on purpose, it's a difficult technique. I wanted them to know that it was ok if they didn't do it right at first and to show them that I need practice too. The important thing is to keep trying. I think this makes me approachable and the idea of science more approachable"* (Post-observation interview, October 4, 2018).

In a similar way, Chad also took extra time to demonstrate difficult techniques or lab processes. While she completed her demonstrations, she pointed out the places in the technique or process that were typical tension points for students. In addition to engaging in this demonstration process prior to the start of every activity, Chad also would pause the lab to review or repeat the demonstration if she felt that it wasn't going well for students. She shared, "I want them to feel comfortable doing science – not just learning concepts – and I want them to be ok asking questions and getting things wrong because that's what we do as scientists" (Post-observation interview, October 19, 2018). In the same fashion, Chad called attention to specific concepts that tend to be burdensome for students while she was teaching them. As she did this, she also provided the reasoning for *why* it's difficult, which made the concept more accessible to students.

Greg also was intentional about providing mechanisms to help reduce student anxiety by making science more accessible. He routinely incorporated examples of how scientists would use a similar lab technique that they were covering and referenced scientific papers where the process was the same, "Here's a published example of how these scientists use the technique you are going to use today to do their research – and I promise you they didn't get it 100% right on their first shot" (Weekly observation, September 28, 2018). Another critical way that Greg intentionally attempted to make science more accessible to students was through a science communication exercise (Figure 4.11). In this exercise, students were tasked to complete a comparison table that identified the attributes of scientific writing (as in published work from the scientific research community) and science writing (as in science communication, broadly speaking).

Scientific Writing vs. Science Writing

Directions: Fill out the comparison table below with your team.

	Scientific Writing	Science Writing
Content (What is written?)		
Motivation (Why write it?)		
Author (Who writes it?)		
Audience (Who is it written for?)		
Source of info (Where is the info coming from?)		
Purpose (Why is this written?)		
Funding (Who is paying?)		
Stakeholders (Who is affected by the writing?)		
Intended Response (What happens next reading it?)		
Review process (Who reviews the work before it is published?)		

Figure 4.11 Comparison table that Greg assigned students to identify the attributes of scientific writing and the attributes of science writing.

Since the assignments and grades were already established for the semester, this activity was optional and ungraded, yet every student chose to participate. As a pre- and post-discussion, Greg asked students how they saw themselves within the science community.

During the pre-activity discussion, students made comments that they felt “outside” the process of science and that they felt it was “rigid” (Weekly observation, November 15, 2018). In the post-activity discussion, students commented that they felt more likely to “do” science communication writing and that their critical thinking skills “matched” that kind of writing better. Greg improvised this entire process after a week where students were disengaged and frustrated during lab time because they felt the language of primary science articles was unnecessarily burdensome. Greg’s actions of responding to student learning needs and making science more accessible to them are mechanisms of culturally responsive science teaching.

To summarize, the findings for Research Question 1 supported the development of four main themes: *Funds of Knowledge, Differentiated Instruction, Intentional Scaffolding,* and *Reducing Student Anxiety.*

Research Question 2: What factors do biology TAs share that influence their decisions to enact culturally responsive science teaching?

In this section, I describe the factors that undergraduate biology teaching assistant (TA) participants discussed as influencing their decisions to enact culturally responsive science teaching (CRST) in their labs. Four major themes emerged from the data: *Affordances* and *Constraints* of engaging in culturally responsive science teaching, *TA Beliefs about CRST,* and *TA Identity*. Figure 4.12 portrays the number of instances that each TA described these themes as impacting their decisions to enact CRST. As described earlier in this chapter, the term *theme* refers to the product of grounded theory analysis wherein individual codes and categories are intentionally reconstructed and elevated to reflect an abstract conceptualization of processes and actions of the participants (Charmaz, 2006). The themes that emerged for Research Question 2, *Affordances, Constraints, TA Beliefs*, and *TA Identity*, each consist of several categories, all described in more detail below, which address the properties and the dimensions of each theme.

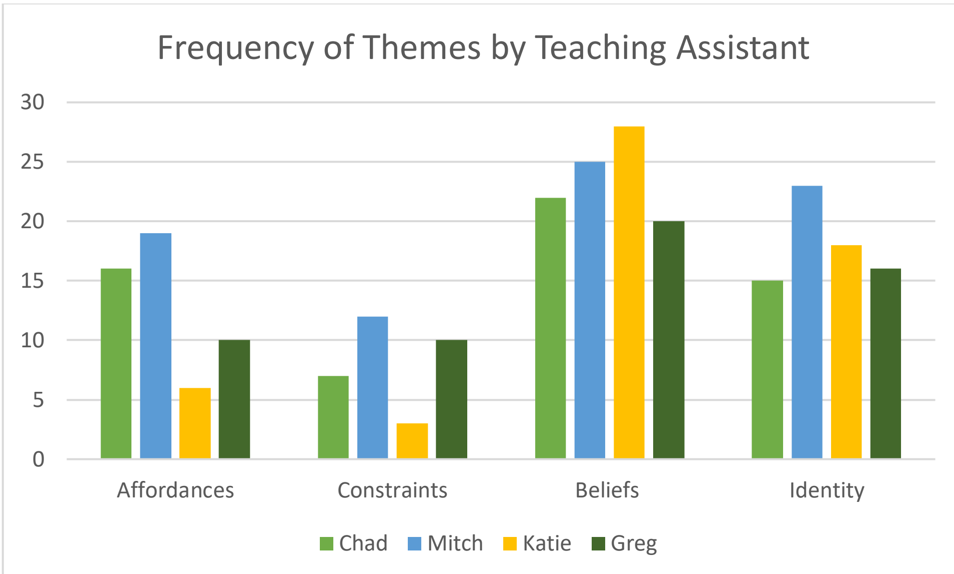

Figure 4.12 Frequency of themes by teaching assistant for Research Question 2.

Affordances. As described by Brown (2009), affordances are "the functional properties that determine how an item may be used" (p.20). In other words (and for this study), affordances are some potential or aspect of the environment that afforded the TAs opportunities to enact CRST. Each TA described various factors that made enacting culturally responsive science teaching easier, more accessible, and more comfortable to them. These *affordances* are described below according to their dimensions: *Training and Exposure to CRST Strategies* and *TA and Student Relationships.*

Training and Exposure to CRST Strategies. There is an important link between teacher self-efficacy and their abilities to enact CRST (Siwatu, 2011) such that it is critical to provide them with "opportunities to develop confidence in their abilities to execute the practice of culturally responsive teaching" (p. 368). Just as the level of self-efficacy impacts how K-12 classroom teachers enact culturally responsive science teaching, so did it influence the TAs at various points throughout the semester. Every TA reflected or shared instances of how their exposure to CRST strategies during the weekly training played a role in how or why they chose to utilize an aspect of CRST in their labs.

Katie described two such instances early in the semester. The first occurred while Katie was leading her students through the introductory material (e.g., overall project goals and activities) prior to the start of their CURE (Course-Based Undergraduate Research Experience), which was an experiment predetermined by the BE faculty to build on an existing database of research that measures changes (e.g., increases, decreases) in the Zone of Inhibition – an area in a petri dish that can be used to determine how susceptible bacteria are to antibiotics – by testing a variety of substances of the students' choosing. Katie connected the procedures of their upcoming experiment with similar procedures they had learned in the previous week's lab. In my field notes, I recorded:

> *"Katie engages students as she demonstrates the micro pipetting process, asking them if they remember the difference between* [pipette plunger] *stop one and* [pipette plunger] *stop two from the previous week. One student says that they do. Katie calls on them by name, inviting them to share out. Student says 'the first stop is the first resistance, because it's the volume' and Katie reiterates and expands on the student's answer, inviting other students to remember last week's material and how they could use it this week."* (Observation field notes, September 25, 2018).

Even though the steps weren't identical, Katie identified that she used this intentional scaffolding and engaging prior knowledge as aspects of culturally responsive science teaching. This is an important aspect of Katie's development as a culturally responsive educator because this was very early in our training, in fact it was my first observation of Katie after our first weekly training session. At that point, I was scaffolding their learning of CRST to allow them to ease into CRST practices through the student-centered action of engaging prior knowledge. This was an important stepping stone for Katie. In our post-lab exchange, Katie shared how she came to the decision to do use that teaching strategy:

> HB: Ok, so can you tell me what things factored into your decision to use CRST today?
>
> Katie: I really like the conversation we had last week about engaging students' prior knowledge and I think it's helpful to [students] to apply procedures that might be hard. It shows them that they already kind of know what they're doing, even if they aren't experts yet.
>
> HB: And were there any things in particular that prompted you to use that [technique]?
>
> Katie: I think that knowing the strategies made it much easier. Being in the training and learning about things that work for students made me feel more comfortable using [CRST].
>
> (Post-lab interview, September 25, 2018).

In another instance, Katie and Mitch reflected that they appreciated the learning environment we had created during our time together in the weekly trainings. During Week 4, we were having an impassioned discussion about building positive science learning experiences for students by identifying and leveraging students' funds of knowledge in the lab. Later in the session as we talked, the TAs all expressed that they felt empowered to explore and enact CRST because of these kinds of conversations. I then gave the TAs these written reflection prompts to build our future conversations: *What does competency in science mean for your students in your lab? What factors do you think influence your students' ideas of success and competency?* and *How do you* *foresee providing spaces for your students to be successful in your lab next week?* The following conversation then took place:

> Katie: Success should look like open, confident participation and asking questions beyond foundational questions. I think that competency in science in my lab means high scores on quizzes, but more so an understanding of procedures, and being able to explain the "why" of each lab.
>
> Mitch: I want to build off what Katie said… I think they should feel that they've learned something useful, that they have a better idea of what science is and how it is performed, and that they feel they did well in the class but whatever "well" means for them.
>
> Katie: Yeah, I think I really appreciate our time here on Fridays because I sit here and absorb all of this info and then I keep thinking about it all weekend. Like next week I want to do more with their funds of knowledge because it worked great last week and being here makes me comfortable trying those things.
>
> Mitch: I think so too. I know for my students, I think they're previous experiences in school and at home concerning what science is influence their ideas of success. For many students, they'll say "oh I just can't do science, it's not my thing," and I think that's got to be in some part the fault of either family or earlier teachers, who let that develop. For these students, they'll just be happy to pass. [using] funds of knowledge can start to erase that, I think. I am glad to have a better understanding of it so I can try it in my lab.
>
> (Weekly training discussion, October 12, 2018).

In this exchange, during the fourth week of CRST training, Katie and Mitch's comments indicate that they perceived the content of our weekly training sessions to be influential in developing their own self-efficacy for CRST. They felt more confident trying out CRST strategies because they had exposure to them in our weekly training meetings.

Likewise, Greg expressed that learning and understanding CRST was an integral part to his ability to enact it in his lab on several occasions. By the fifth week of training, for example, Greg had tried a few CRST strategies in his lab section, such as engaging students' prior knowledge, making content relevant to students' lives, and building positive science learning spaces. When he began utilizing funds of knowledge connections by asking students to describe how they solve a problem and why they approach it in that way, Greg reflected that it was "easier and less awkward to implement [funds of knowledge-eliciting strategies] because we have been talking and learning about it for a few weeks now" (Post-lab interview, October 19, 2018). For Greg, the learning environment of the weekly trainings was an important affordance toward his enactment of CRST. Of all of the TAs, Greg was the most likely to implement aspects of CRST that we talked about during the weekly trainings 'as-is' (as opposed to adapting these CRST connections in other ways and for other contexts).

Lastly, Chad also indicated that exposure to CRST strategies was a factor in her ability to enact it. In this instance, Chad described how learning about CRST with specific goals helped her to know what additional information she needed to gather before she enacted an aspect of CSRT:

> HB: Can you tell me what things influenced your decisions or abilities to use CRST today?
>
> Chad: The weekly goal setting that we do at the end of our training is helpful. I wanted to make today's heartrate lab relevant to students and I think I did that really well today.
>
> HB: Can you talk more about why the goal setting is helpful?
>
> Chad: In this case, I know how to make the heartrate lab relevant to *me* and I can use my scuba diving and how cold-water effects [heartrate]. But the goalsetting helped me to identify that I didn't know enough about the students to do it like that.
>
> HB: And so what was your approach then?
>
> Chad: I did minute-papers at the end of last week's lab to ask them to tell me their favorite outdoor activity. Then today when I introduced [the lab] I was able to talk

> about things that effect heartrate like mountain biking in the summer versus winter and then I used my personal example.
>
> (Post-lab interview, October 19, 2018)

One of the routine aspects of the weekly training meetings was that TAs were asked to complete a brainstorming and goal-setting writing exercise wherein they articulated what specific strategies or aspects of CRST they hoped to enact the following week. In this exchange, Chad noted that the process of explicitly writing out those goals was particularly helpful, indicating that the goal-setting exercises were an affordance while enacting CRST.

TA and Student Relationships. The TAs also articulated that the relationships that they had with their students significantly impacted CRST enactment in their labs. Chad explained that the community and trust building she had worked up to with her students played a role in how confident and comfortable she was trying out new things in the classroom, "I think them knowing me and being cool with me helps me tell them what they need and what they need to do for the class and I think they trust me and they respect me," (Weekly reflection, November 2, 2018). The foundation Chad had built of trust and comfort with her students was an affordance as she enacted CRST. For Chad, having spent time building relationships with her students made her feel more confident that when she tried a CRST strategy, it would be well-received.

Mitch had similar conceptions about how relationships impacted his ability to enact CRST. He explained that when the students were more comfortable with him, they were "more likely to voice when they are confused" (Weekly reflection, October 26, 2018). This was very important to Mitch given his reasons for wanting to enact aspects of CRST:

> *"A lot of the activities I did this semester were really new – like our culturally responsive stuff. I had a shift in my thinking this semester, where I got much less stressed about getting through all of the material. If we cover 75% of the material really well and all my students have that information, I feel like that's better than covering 100% of the material with 50% comprehension. But I really relied on the relationships I had built with them throughout to feel confident that it was the right approach."* (Post-lab interview, November 29, 2018).

Mitch felt he could be more responsive to his students and utilize culturally responsive science teaching because he felt his students trusted him to share part of their understanding or lack thereof. For Mitch, the quality of engagement with the science content was more important than quantity. Furthermore, it was those trusting relationships that assured Mitch that CRST was a valid, worthwhile approach to science teaching.

Katie explained that the student-to-student relationship was also critical to her success in implementing CRST. Gauging whether or not there was an appropriate moment to use a CRST strategy, Katie said, was determined largely by how well the students interacted and how they were building their own communities (Weekly reflection, October 4, 2018). I observed the following occur during one of her labs:

> *"From her goals, I saw that Katie had planned to integrate a partner exercise during her lab. But she is now breaking the students into groups of three and assigning them all roles. They are to each take a turn being the leader/teacher, the reporter, and the timekeeper."* (Observation field notes, November 13, 2018).

After observing her change her planned activity to a more nuanced aspect of CRST where students are given the opportunity to act as experts, I asked about that decision. She responded, "They looked slightly confused and uncomfortable and I wanted the conversation to be more productive than just a back-and-forth between two people," (Post-lab interview, November 13, 2018).

Constraints. Constraints can be described as the opposite side of the coin than affordances (Brown, 2009), or factors about the environment that restricted TAs' abilities or decisions to enact CRST. Brown (2009) positions constraints as negative – such as barriers or impediments – and those that can positively confine options for educators. In the context of this study, constraints are described more in terms of the barriers TAs described when enacting culturally responsive science teaching. Therefore**,** the theme *constraints* emerged as a factor in TAs abilities and decisions to enact CRST. In the following subsections I describe the dimensions of this theme: *time* and *limited autonomy in lab design.*

Time. Table 4.1 shows the number of weeks out of the 10-week training period that TAs referenced time as a constraint on their ability to enact CRST. Though not prompted to discuss time, every TA referenced time as a limiting factor, and Mitch and Katie demonstrated the highest frequency of weeks where time was an issue.

Table 4.1
Weeks in Which Time was Discussed as Impeding CRST

	Number of Weeks (out of 10)
Mitch	8
Katie	8
Greg	4
Chad	3

We discussed this constraint during our weekly training sessions at multiple time points. The following conversation took place during training on November 2, 2018:

> HB: Ok, let's just take a minute while we're all together to debrief. How did things go for you [in lab] last week?
>
> Greg: I can start. My biggest issue last week was just the time.

> HB: You didn't have enough time or are you talking more about timing with your activities?
>
> Greg: I felt really rushed for time so it made [CRST] challenging.
>
> Katie: That's how I feel every week! Our labs for each week are so jam-packed with activities. It's overwhelming to begin with…so I really have to plan my [CRST] activities carefully.
>
> Mitch: I would echo that too. Sometimes having a tight schedule is good so we can keep students closely on track, but a lot of times it's stressful. I literally have everything planned out to the minute.
>
> HB: To the minute? That sounds very hard.
>
> Chad: Yeah it does. There are days that I have the whole lab session full of activities and time is short, but I don't usually have to plan to the very minute.

Additionally, both Mitch and Katie predicted that adequate time in their lab will be troublesome in their weekly goalsetting and during our training discussions. Table 4.2 illustrates that during the goalsetting activity, which occurred the week prior to the lab TAs intended to enact their goals, both Katie and Mitch expected that time would be a constraint in their ability to enact CRST.

Table 4.2

Excerpt of Weekly Goalsetting

	Date	Weekly Goals	Concerns
Mitch	October 5, 2018	"Connect CURE materials to students own funds of knowledge."	"There may have been one student who was just really, really excited about this set of compounds, and they were the reason the group chose them. As such, it might be difficult to engage group members besides this one person. It's hard with limited time in the lab to build in extra activities"

Katie	November 2, 2018	"Add an assessment to next week's lab to determine measures of success/competency."	"That there will be an overwhelming amount of things students really don't understand, how to best present the information with already limited time?"

Here the TAs voiced that the time demands already imposed by the structure of the lab made instruction "stressful" and CRST "challenging" to incorporate in the ways they desired to do so. In this example, Katie and Mitch indicated that CRST strategies were potentially less likely to occur because the quantity and structure of lab activities made it difficult to even gauge general student understanding; CRST activities would be even more difficult to incorporate.

Limited Autonomy in Lab Design. Similar to the constraint of time, the TAs also shared that the lack of autonomy they had over their lab design – content, activities, summative assessments, etc. – was sometimes a barrier to their ability to enact CRST.

Chad described how this impacted her during two different weeks. When she was preparing her CRST goals for a lab that was focused on reproductive health, sexual activity, and sexually transmitted diseases, Chad felt that it was important to "create a more inclusive and safe space since the topic had the potential to be awkward for some students" (Post-lab interview, November 30, 2018). She wanted to incorporate additional slides and handouts that could provide additional information about the topic, but was not allowed to because the curriculum was already pre-determined as lab curricula for each biology course is designed in advance by department faculty and lab coordinators. Chad reflected that the lack of autonomy "confined" and "limited how she did CRST" (Post-lab interview, November 30, 2018). Similarly, Chad expressed feeling liberated when she was invited to co-create a portion of a new lab that the department was trying out:

> *"We* [the students and Chad] *got to walk around and talk a lot* [about the lab procedures and content]. *I also asked them to write a question as a group and we discussed them in the end. I thought the freedom of this lab, and since I wrote it and did it, allowed me to feel comfortable about doing [CRST] things and not getting into trouble!"* (Weekly reflection, December 6, 2018).

Chad was able to feel more confident in the ways she enacted CRST in her lab when she had some autonomy in how the lab was designed. She expressed that knowing the reasons behind why the lab was organized a particular way helped her to feel more sure about the places she tried to enact CRST (Focus group, December 7, 2018).

Greg also described how having no autonomy or ownership in the lab design made it difficult for him to feel confident modifying his labs for CRST.

> *"I feel better when the culturally responsive kind of things I can do are easily assimilated into the day. I don't have control over the lab priorities, and I don't always feel confident modifying things to add [CRST] stuff."* (Post-lab interview, October 26, 2018).

TA Beliefs. An emergent theme over the course of the semester was that TAs beliefs about science teaching and learning were connected to their decisions surrounding how to enact CRST. The following subsections describe two salient dimensions of this theme: *beliefs about science teaching* and *beliefs about science learning*.

Beliefs about Science Teaching. All four TAs reflected that their beliefs about what science teaching was to them – and what they thought it should look like – impacted how they thought about enacting CRST in their labs. The TAs described that their beliefs influenced their CRST enactment decisions. This included their beliefs that science teaching should empower students in their science learning, that it should focus on science process skills, and that it should be engaging to students. Generally speaking, all TAs approached science teaching with an asset-based view of their students, which is a key aspect of CRST (Ladson-Billings, 1994).

In the following interview, Mitch talked about how he felt CRST fit in with his beliefs about science teaching.

> Mitch: The biggest thing that bothers me is when people say "I'm not a science person." This is my privilege speaking – my parents really pushed learning/reading/critical thinking all the time, I went to a really great school district – everything that I wanted to learn I had the time and resources for. It's true that anybody can learn anything but resources are often prohibitive and that's why we have people who come into science classes thinking they can't. And that's why good science teaching is critical.
>
> HB: And what does good science teaching mean to you?
>
> Mitch: I think science teaching in our level is lacking process skills versus the focus on content knowledge. For one thing, relatable-ness and connections with students are really hard to make if we just focus on content and what can be lost can be the reasons for doing stuff. The "why" is missing. And I think culturally responsive teaching can help get more at that.

In this exchange, Mitch said that he believed science teaching should be focused on process skills rather than the content-focused approach he felt was prominent in undergraduate science instruction. For him, building those skills is also a way to make meaningful connections with students and that students need to know the reasons behind the content. I asked him to elaborate more on how those beliefs fit in to his teaching specifically:

> Mitch: Making the "why" explicit is very helpful I think; the more memorable lectures for me were from people when they are talking about applications [of science] and whenever it can be related to real-world. Also areas where I've learned why professors are teaching the way they are is helpful, I think. Students

> are open to the tools we talk about in culturally responsive teaching; teaching isn't about being secretive about the reasons for why.
>
> HB: So how do you think this aspect – your views about teaching – factored into how you taught in culturally responsive ways?
>
> Mitch: It made me feel like my teaching had a bigger purpose than just getting through the content, for sure. It also sort of reaffirmed that the way I think about science teaching is valued in a broader community.
>
> (Post-semester interview, December 7, 2018).

Mitch described that his own science learning experiences were integral to the development of the beliefs he currently holds about science teaching. He believed that students are more likely to be engaged in their own science learning and see the value of science from a broader perspective if the teacher could lead them to those connections by making the "why" of science explicit. A similar thread was evident throughout Katie's reflections about science teaching:

> *Katie:* Foremost belief is that your students should learn something from your teaching. If your students aren't grasping the topic, there should always be some innovation to meet those needs. That finding new ways to relate information started for me before I was a TA. I noticed some of my professors would be better than others – the ones who were better cared about if I really knew the information. This happened outside of science classes more often. There was a solid group of science faculty who did that as well.
>
> HB: Can you expand on what you mean by "did that"?
>
> Katie: When professors were teaching in ways that gave students a stake in the content. I noticed how much more knowledge I gained when they did that. I got better grades in the class, but I also noticed that the professors who did that didn't allow me to just be a sponge in their class. Even though people groaned about the partner conversations, the profs who engaged me to really think more about my own knowledge then I was learning more and making direct connections about my own knowledge and learning.

Katie also drew on her own science learning experiences as she described her beliefs about science teaching. For Katie, the onus of student understanding should be predominately on the teacher and the ways in which they innovate their own teaching to meet students' needs. She also indicated that it was important for her to make direct connections between her own knowledge and the learning activities that contributed to her knowledge, meaning she felt it was important that science teaching be explicit about why certain activities were being implemented. I asked her to expand more on that:

> HB: Clearly your science teaching beliefs are shaped by good and bad experiences you've had. How does this impact your approach now?
>
> Katie: One of the things that never worked for me was when I was constantly asked to apply something I didn't understand just for the sake of a technique like active learning. I really like the approaches we have learned and applied with culturally responsive teaching because I think it's easier for students to achieve understanding. So then applying the knowledge is really useful.
>
> HB: Can you share anything about if or how these beliefs impacted your culturally responsive teaching?
>
> Katie: I think that I have always been a teacher that tries to be culturally responsive – I just didn't know it was called that. So I think I've always held these views and they've always shaped my teaching, but now I know how to talk about it from a teaching standpoint.

(Post-semester interview, December 13, 2018)

Katie explained that she believed that CRST would improve students' understanding of science content and that it was also important to engage students in understanding the reasons for why she uses particularly teaching techniques in order for them to connect to their own science learning. Katie reiterated that she felt one of the ways she enacted CRST was through creating meaningful science learning experiences for her students.

Greg shared explicit points that he believed constituted good or effective science teaching. For Greg, science teaching should focus on creating buy-in with students:

> Greg: I have two kind of main parts to what I believe. One is that the transfer of information should flow from a clear conceptual grounding. And two is making sure you're creating a product that's engaging enough where students feel like they are spending their time and money on an experience that they can actually learn and take away. Teaching should be more than reading from a textbook, and science teachers can do more to make that happen.

Greg indicated that it was important to create useful experiences for students in undergraduate science courses in order to achieve meaningful science learning. Part of that experience, for Greg, includes establishing a conceptual grounding – or a foundational basis in which subsequent science learning can build, such as science process skills. I asked him to talk more about how he envisioned that happening.

> Greg: Well I think there's sometimes an emphasis on students being just one dimensional and absorbers of knowledge. Curriculum writing is very focused and trying to be objective as possible – but a lot of times on our end, we're given the curriculum but we're not really told how to apply it to other people's learning styles our own teaching philosophy.
>
> HB: And how do you see this work in culturally responsive science teaching fitting in with that?
>
> Greg: I think it has helped in knowing how to *teach something but not just preach something* – teaching is more than people just talking at you – teaching is not a one-way flow from instructor talking to the students. I think [CRST] is interactional teaching, with motivating (internal or external) factors for students.

(Post-semester interview, December 11, 2018)

Greg explained that he believed the responsibility of the educator was to teach science in multidimensional ways and also that multidimensional teaching meant not just standing at the front of the room and "preaching" to students. He felt that CRST fit those beliefs because it was interactional and positioned students to engage in their own science learning as opposed to merely absorbing information.

Chad shared similar beliefs as her peers about science teaching, reiterating a trend that TAs beliefs about science teaching are formed by their own science learning experiences as well as relate to their decisions to enact culturally responsive science teaching.

> Chad: As a student I was never one to volunteer an answer because I didn't want to be wrong. But had a couple influential teachers that made it better by saying jokes to make a point. They were more casual, so there was less of a power dynamic. I think candidness is very cool and you don't need to know everything to be a good teacher.

Here Chad indicated that she believes there is a power dynamic that occurs in science learning spaces that keeps certain students from engaging in the material. I asked her to describe how those beliefs influenced the ways she enacted CRST:

> Chad: I think undergraduate science teaching is filled with a lot of rigid facts, rigid power dynamics. The teacher lectures and you listen and watch, you go home and study, come take the test. And then you do it again. It puts the onus solely on the students and it needs to be more that the teachers try to get students more involved in their own learning.
>
> HB: What does that look like for you, in your lab?
>
> Chad: I try to help them get over what everyone feels worried about right away and make it clear that we are all learning. I don't have to be the only knowledge keeper and I think my students react well to that.
>
> (Post-semester interview, December 11, 2018).

Chad described that she holds the belief that science teachers need to take more responsibility for students' learning. She also indicated that disrupting the power dynamic that places science teachers as the only expert in the room was very important.

Beliefs about Science Learning. The TAs expressed that their beliefs about what science learning should be and what the students' roles in learning should be both influenced their views about CRST. The following outlines how the TAs discussed their science learning beliefs during the focus group on December 7, 2018. All quotes are from this date.

Katie described her beliefs about science learning:

> "*On a bigger scale, everyone should always be trying to learn – maybe not at a university level but there's so much information out there – grow and expand your mind…even if you're not particularly interested in it. I took an econ class and now feel like I can understand more and talk more about things – like our students who are like "I'm not a science person" – that never helps you – everyone should be trying to learn at all times. Start with science and make it relevant to your other interests."*

For Katie, science learning is a life-long endeavor and should not be restricted to formal science learning environments. She believed that a key aspect of science learning should be how people can relate science to their own lives. Katie further described how she felt her beliefs contributed to the application or enactment of CRST:

> "*The point of CRST to me is to find the gifts and talents that every person brings and use those gifts to engage other people in the science learning process. The teacher is not the gift. It really has to come from the students – they should be wanting to have control of their learning and wanting to have control of their experience. And I think CRST helps us get there. The student should be the guide of the class – there shouldn't be one single voice of all-powerful wisdom in science classes because we are all producing knowledge. Students should feel empowered in that way."*

Katie's beliefs about student agency and empowerment in their own learning were integral to her views on CRST and her enactment decisions.

Like, Katie, Chad also drew on her beliefs about science learning to describe how and why she made CRST enactment decisions. She shared,

> *"I teach in the way I've seen things that are effective for science learning. So to go back in forth between TA and Student in my mind is important. As a student, I am trying to figure out what they are thinking since I've been there then I can go back to thinking as the TA and how they are engaging in their science learning."*

For Chad, the role of the student was a critical aspect of science learning as well the reasons she engaged in CRST. She continued,

> *"I tell them that there are certain things that is in the curriculum that they will not easily relate to, but that if they try I will try to make it digestible and we basically have this agreement for the whole semester. So for some students, this is the only Bio course they are going to take. Sometimes I ask a question and people will just stare at me – so try to ask a smaller less complicated question so they will attempt the harder ones – build them up by scaffolding both content and self-confidence. I see that as culturally responsive."*

In this example, it is clear that Chad's belief about CRST as scaffolded learning was an integral part of her enactment decisions.

Similarly, Greg described how his views on science learning impacted his CRST.

> *"Being an effective learner is kind of realizing that learning is more than sitting there and passively gaining knowledge – it's interacting with it (knowledge/content) in some kind of dimension. Whether with people or on your own – it always seems to be a hump between actively and passively learning which kind of deters a lot of people – the process of getting over that hump is both the responsibility of the learner and instructor."*

For Greg, science learning should be interactive and the responsibility to engage in the learning process lies with both the learner and the teacher. This belief was important to Greg's views of himself as a culturally responsive science teacher:

> *"I'm trying to be as student centered as possible and be culturally responsive, which probably feeds back into what I see missing as science education as a learner – that instructor attention and feedback. I personally want to have that interactive experience with teachers and have a learning experience that is engaging – so would be hypocritical for me to not do that in my class."*

TA Identity. TAs' identities and how they viewed their identities contributing to CRST became an important and emergent theme for Research Question 2. At one point during the semester, TAs completed an inventory of the aspects of their identities that influenced them as teaching assistants. Building on that self-reported identity profile, each TA shared how they felt their identities impacted the ways they both taught science and enacted culturally responsive science teaching. Those impacts differed across the TAs and are described in further detail below.

Chad. Chad initially shared that she was leery to allow her identities to play significant roles in her teaching because of her own experiences with instructors or professors who had attempted similar things in courses she had taken:

> *"I don't really strongly try to incorporate race/religion/sex/gender/sexual orientation and such. I think at best, it could make some students feel more comfortable, but at worst it could make people alienated and feel targeted. As a person of color myself, it was always SUPER weird when other people tried to relate it back to my culture, which is actually not Asian because I am transracial. I think it can help many, but it definitely does not help others, so I keep my classroom neutral since I am a person connecting with people first and foremost. I also think I have a subliminal benefit because I am a person of color, other people of color give me the benefit of the doubt, which I also give to other people of color."* (Weekly brainstorming and goalsetting, October 19, 2018).

Chad's previous experiences indicate that she felt some educators superimposed aspects of culture in inappropriate ways or places, which contributed to her both her perceptions of CRST as well as how she viewed her own identities as impacting her teaching. Table 4.3 is Chad's identity profile.

Table 4.3

Identity Profile Completed by Chad

Identity	Identities you think about most	Identities you think about least	Identities that have a strong effect on how you	Identities that impact your science learning	Identities that impact your science teaching

			perceive yourself		
Race		X			
Ethnicity		X			
Religious or Spiritual Affiliation		X			
Socio-economic Status		X			X
Gender		X			
Sex		X			
Age		X			X
Sexual Orientation		X			
Academic	X		X	X	X
Professional	X		X	X	X
Family	X				
Friends	X				
Partner/Significant Other	X		X		
Other					

For Chad, her age, academic, and professional identities influenced the ways she taught science and enacted culturally responsive science teaching. Chad explained that her identities informed the ways she *didn't* want to enact culturally responsive science teaching, "so my identity is a person motivated by people. I enjoy helping others learn and fixing others' problems, so my classroom is not focused on anything else but learning and building relationships," (Weekly brainstorming and goalsetting, October 19, 2018).

Chad felt her identities intersected with her teaching with various ways. The following reflections are Chad's responses to writing prompts specific to identity. The first prompt was *Do any of these identities matter as you're trying to use the culturally responsive/inclusive strategies we've been talking about this semester?*

> *"I do recognize that there is a benefit to adding in some things for cultural inclusion, but I just don't know how to in a way that is truly beneficial for all and does not cause mixed feelings"* (Writing prompt response, October 19, 2018)

In this response, it is clear that Chad holds beliefs that some aspects of CRST are too related to cultural inclusion and that those aspects of students' identities may not be an ideal asset to draw on in science learning spaces. Next, Chad reflected on the prompt *Can describe your views, thus far, on culturally responsive & inclusive teaching? How do any of your identities inform these views?*

> *"I think science is not related to culture. I do however think that teaching anything can be culturally linked. I don't identify with a culture so much (besides American), so most of the way I teach is American style. I think that this is appropriate because this is America. For students who are not Americans, I have been in their shoes as an exchange student. I think that there are certain jokes or cultural themes that they miss out on, but I think that is literally part of the exchange process. You go to another country for cool opportunities and to learn about another culture. When I am using "American" culture in the classroom, I do try to put a blanket statement out saying that people can believe whatever and retain whatever they want from class, but that it is ok if you don't. I make this statement with evolution because not everyone is the same religion. I think I had a kid say something about black people and sickle cell anemia, so I said that it is more common there based on evolution because sickle cell trait is good for anti-malaria. I then said that there are a few other "races" that have higher proportion of a disease. (lactose intolerance in non- Europeans, cystic fibrosis in whites, and so on…)"* (Writing prompt response, October 19, 2018).

Here, Chad expressly connects culture with race and ethnicity in her conception of how culture relates to teaching and also to science, yet she acknowledges race as a social construct later in her reflection. At this point in the weekly trainings, the TAs were just beginning to interrogate what is meant by the term *culture* in relation to science teaching.

Mitch. Mitch felt his identities influenced his teaching in several ways. Table 4.4 is Mitch's identity profile.

Table 4.4

Identity Profile Completed by Mitch

Identity	Identities you think about most	Identities you think about least	Identities that have a strong effect on how you perceive yourself	Identities that impact your science learning	Identities that impact your science teaching
Race	X		X		X
Ethnicity		X			
Religious or Spiritual Affiliation		X			X
Socio-economic Status		X	X	X	X
Gender	X		X	X	X
Sex		X			X
Age		X			X
Sexual Orientation	X		X	X	
Academic	X		X	X	X
Professional		X			
Family		X			
Friends		X			
Partner/Significant Other		X			
Other					

For Mitch, his race, religious or spiritual, socio-economic status, gender, sex, age, and academic identities most influenced the ways he taught science and enacted culturally responsive science teaching. Mitch identities intersected with his teaching with various ways. The following reflections are Mitch's responses to writing prompts specific to identity. The first prompt was *Do any of these identities matter as you're trying to use the culturally responsive/inclusive strategies we've been talking about this semester?*

> *"I think so! For one, I am really working to become more conscious of how students may react to being taught by a white male. I think it make some students feel more confident in my teaching, but alienate other students. As such, it's important that I work to incorporate my student's own opinions and perspectives to make sure my teaching is impartial, compassionate, and effective for all of my students. In a very different way, I do think about my sexuality when teaching. My*

> *sexuality has had deeply rooted effects on my personality and how I present myself. I think it has made me an emotive speaker, and more confident in the long run. However, I do still worry that at times my credibility or ability to relate to a student could be impacted by their own biases"* (Writing prompt response, October 19, 2018).

Mitch reflected that because certain aspects of his identity greatly influenced his teaching – such as the way he presents himself – he also felt it made him more aware of how his students' identities play a role in their own learning. Next, Mitch reflected on the prompt *Can you describe your views, thus far, on culturally responsive & inclusive teaching? How do any of your identities inform these views?*

> *"I was raised in a very liberal, generally atheist, science-oriented family, so for me evolution was never anything controversial, and I had heard a lot about it before coming to college, even outside of classes. As such, I still have to consciously reflect on the fact that some of my students may not have learned anything about evolution or may be hostile to the very concept.*
>
> *I also need to keep in mind my previous experiences when looking at CURE projects. Many of my students hadn't read any scientific literature before taking this class. No-nos like discussing an experiment like a narrative, or using non-objective language does not even occur to these students, while to me they seem so obvious. This doesn't mean I can't hold my students to that standard, I just have to make sure to explain it to them before they turn in work, and provide examples for them to use. This also applies to their CURE PSAs. I feel very comfortable speaking in front of an audience, so I don't even think of that as a challenge. But some of my students truly, truly hate it. So again, I still think it's important for them to do, I just need to structure it and encourage them in a way that they feel more comfortable presenting" (Writing prompt response, October 19, 2018).*

Mitch again described how his awareness of his identities causes him to also be cognizant of how students may or may not be impacted by their identities in their own science learning. This influences how he teaches science. Specific to CRST, Mitch continued:

> *"I really wasn't sure what culturally responsive teaching was before I entered this seminar. I thought it was more like, "How do you use the right pronouns?" or "Use these teaching strategies for this community." Obviously, this is*

ridiculous, and impossible to really apply. What I've learned is that culturally responsive teaching applies to all students and all identities, even if they don't seem to be in a marginalized community, and revolves around using student's own skills to help them learn. It's student-centered learning, and as such, the skills I've learned are far more flexible and practical than something concrete to a specific group" (Writing prompt response, October 19, 2018).

Mitch's closing reflection demonstrates the he sees the connections between identity, science learning, and CRST as being both inextricable and integral to enacting CRST.

Katie. Identity played a large role in Katie's approach to science teaching and CRST. She noted that:

> "I have a teaching identity – I definitely think that being a TA legitimized my internal thought of having a teaching identity – there are many instances that I felt like I was teaching people in different ways and showing them something new that they hadn't seen/known before" (Weekly training session discussion, October 19, 2018).

Table 4.5 is Katie's identity profile.

Table 4.5

Identity Profile Completed by Katie

Identity	Identities you think about most	Identities you think about least	Identities that have a strong effect on how you perceive yourself	Identities that impact your science learning	Identities that impact your science teaching
Race			X		
Ethnicity			X		
Religious or Spiritual Affiliation		X			
Socio-economic Status	X		X		X
Gender	X			X	
Sex	X			X	X
Age	X				
Sexual Orientation		X			X

Academic	X		X	X	
Professional	X		X	X	X
Family	X				
Friends	X				
Partner/Significant Other	X				
Other					

For Katie, socio-economic status, age, academic, and professional identities most influenced the ways she taught science and enacted culturally responsive science teaching. Katie identities intersected with her teaching with various ways. The following reflections are Katie's responses to writing prompts specific to identity. The first prompt was *Do any of these identities matter as you're trying to use the culturally responsive/inclusive strategies we've been talking about this semester?*

> *"Yes. My teaching is somewhat centered around being a non-biology degree seeking student showing that this content is important. I also noticed in my science career that I had few personable professors while I have had many within the English department. My identities push me to be candid with my students while also showing that biology lab can be something fun and interesting"* (Writing prompt response, October 19, 2018).

Katie described that her identities influenced the ways she interacted with her students as well as her desire to show students that science was both interesting and something accessible to them. Next, Katie reflected on the prompt *Can describe your views, thus far, on culturally responsive & inclusive teaching? How do any of your identities inform these views?*

> *"I have been thinking about this topic a lot recently and how cultural responsiveness and inclusivity can be applied to a lot of different areas. In teaching, I have already noticed a difference in the knowledge outcomes of my students and therefore really believe in the process. Based on my identity, I think that every student should know that someone cares that they are learning"* (Writing prompt response, October 19, 2018).

Katie's closing reflection shows that she incorporated aspects of herself – her identities – as she engaged her students in CRST. To her, being inclusive to her own identities as well as those of her students was a practice of CRST.

Greg. Identity also played a role in how Greg approached science teaching, learning and CRST. He said:

> *"I approach teaching from a learning-first perspective – at the end of the day whether you are a student or an instructor -you're all there to learn something. I do this because not everyone has a science identity when they come to class –I like having an open mind to that then I can change my own thinking and open my mind to other ways of thinking, especially for students who aren't coming from a science background"* (Weekly training session discussion, October 19, 2018).

Table 4.6 is Greg's identity profile.

Table 4.6

Identity Profile Completed by Greg

Identity	Identities you think about most	Identities you think about least	Identities that have a strong effect on how you perceive yourself	Identities that impact your science learning	Identities that impact your science teaching
Race	X		X		
Ethnicity					
Religious or Spiritual Affiliation		X			
Socio-economic Status					
Gender			X		
Sex			X		
Age			X		
Sexual Orientation					
Academic	X			X	X
Professional	X			X	X
Family	X				
Friends	X				

Partner/Significant Other	
Other: Born in U.S. or Overseas	X

For Greg, academic and professional identities most influenced the ways he taught science and enacted culturally responsive science teaching. Greg's identities intersected with his teaching in a few ways. The following reflections are Greg's responses to writing prompts specific to identity. The first prompt was *Do any of these identities matter as you're trying to use the culturally responsive/inclusive strategies we've been talking about this semester?*

> *"Most of these identities will matter when I'm trying to develop plans for teaching in a culturally responsive way. However, I think there is an emphasis on identities that are more internal such as academic, professional, family and friends since those are factors that make people unique, allowing them to diversify a conversation about the subject. Academic and professional in particular because those determine your qualifications for the job. However, factors such as race, gender, and sex may have a role in how others perceive you and how much they trust you"* (Writing prompt response, October 19, 2018).

Here, Greg discussed both the aspects of his identities that influence how he teaches and prepares to teach each week. He also makes an important distinction that he is aware of how other people perceive his identities also influences the way he conducts himself as a TA. Lastly, Greg reflected on the prompt *Can describe your views, thus far, on culturally responsive & inclusive teaching? How do any of your identities inform these views?*

> *"I think culturally responsive and inclusive teaching is important to make sure everyone has a chance to participate in the discussion and also have their interests engaged in the learning process. While being in a minority group does have an effect of why I think CRST is important, personality also likely plays a role and my own desires to make sure everyone is included in the learning process and that everyone can be a good citizen"* (Writing prompt response, October 19, 2018).

Greg again reiterated that his identities play a role in his teaching and pointed out that personality also influences how he enacts CRST.

To summarize, the findings for Research Question 2 supported the development of four main themes: *Affordances* and *Constraints* of engaging in culturally responsive science teaching, *TA Beliefs,* and *TA Identity*.

Postcolonial Critique

As described in chapters 2 and 3, postcolonial analysis is an emerging and dynamic framework that aims to delve more deeply into the ways that colonial legacies manifest in actions, processes, and structures today (Ashcroft, Griffiths & Tiffin, 1995; Bhabha, 1994; Fanon, 1961; Said, 1978; Smith, 1999). While there aren't static boundaries for how this critique should be actualized in research, several scholars have paved the way for postcolonial analysis to function as a *re-read* (Carter, 2004, 2006), or secondary look, of the data. Therefore, this section interrogates the findings for both research questions from two postcolonial vantage points that are particularly salient in science education: *Settled Assumptions* and *Bounded Knowledge*. These will be defined and detailed in their respective sections below.

Settled Assumptions. Carter (2006) describes assumptions in Western science from a postcolonial perspective as the "assumptions bound to stable and unitary ideas of nation, culture, identity, comparison, and difference" (p. 681), such as those ideas in science and methodologies that place humans as objective and removed from the natural world. Furthermore, these settled assumptions in Western science create a platform on which science and culture are separate paradigms, one that elevates Western science as superior and relegates culture to social sciences (Harding, 2008).

To explore the dimensions of these “taken-for-granted assumptions” (Bang et al., 2012, p. 317), I examine more critically the reasons TAs shared for their enactment decisions (RQ2). Across all four TAs, their enactment decisions could be seen in four major themes: affordances, constraints, beliefs, and identity. In this postcolonial reread, I look more deeply at TA beliefs and identities.

Below is the transcript from a post-observation interview with Mitch, also discussed in the previous section:

> *Mitch: The biggest thing that bothers me is when people say “I’m not a science person.” This is my privilege speaking – my parents really pushed learning/reading/critical thinking all the time, I went to a really great school district – everything that I wanted to learn I had the time and resources for. It’s true that anybody can learn anything but resources are often prohibitive and that’s why we have people who come into science classes thinking they can’t. And that’s why good science teaching is critical.*
>
> *HB: And what does good science teaching mean to you?*
>
> *Mitch: I think science teaching in our level is lacking process skills versus the focus on content knowledge. For one thing, relatable-ness and connections with students are really hard to make if we just focus on content and what can be lost can be the reasons for doing stuff. The “why” is missing. And I think culturally responsive teaching can help get more at that.*

In this exchange, Mitch shares his beliefs about ‘good’ science teaching, which emphasizes “relatable-ness and connections with students” while also acknowledging external resources that are often inaccessible. Digging deeper, it is also evident that Mitch interprets the focus on science content knowledge in the lab curriculum as prohibitive in making connections and being relatable with students. This contention is an example of an opportunity where Western science and science learning could be reconceptualized as a relational and holistic, as opposed to the essentialized focus on process skills through content knowledge. From a postcolonial perspective, Mitch's responses indicate that in science, representation of who can be a scientist is based on the mastery of specific science content, rather than science content's relation to a learner's sociocultural experiences (Loomba, 2015; Smith, 1999). Relational science learning aims to create "critical shifts in ways of thinking about core and emergent phenomena related to life" (Bang et al, 2012, p. 307) and in the example of Mitch, such shifts might include a re-focusing on the ways of knowing specific to a particular lab rather than facts to be internalized.

Through her reflections on beliefs about teaching and her identities, Chad also demonstrates how engrained the settled assumptions of science are in science learning. Below is an excerpt from my findings section:

Here Chad indicated that she believes there is a power dynamic that occurs in science learning spaces that keeps certain students from engaging in the material. I asked her to describe how those beliefs influenced the ways she enacted CRST:

> *Chad: I think undergraduate science teaching is filled with a lot of rigid facts, rigid power dynamics. The teacher lectures and you listen and watch, you go home and study, come take the test. And then you do it again. It puts the onus solely on the students and it needs to be more that the teachers try to get students more involved in their own learning.*
>
> *HB: What does that look like for you, in your lab?*
>
> *Chad: I try to help them get over what everyone feels worried about right away and make it clear that we are all learning. I don't have to be the only knowledge keeper and I think my students react well to that.*

(Post-semester interview, December 11, 2018).

Chad described that she holds the belief that science teachers need to take more responsibility for students' learning. She also indicated that disrupting the power dynamic that places science teachers as the only expert in the room was very important.

Chad is disrupting a settled assumption in science that there is one knowledge-holder in the room, similar to the settled assumption in science that there is an objective truth to be found (Bang et al, 2012; Smith 1999). Her actions in desettling the expectations of science learning are as much an act of resistance as they are integral to creating student agency.

Chad also demonstrated the how the nature of settled assumptions in science can be constraining to beliefs about CRST. Below is an excerpt taken from my findings surrounding how the TAs interpreted their identities in relation to their beliefs about science and science learning.

Next, Chad reflected on the prompt Can describe your views, thus far, on culturally responsive & inclusive teaching? How do any of your identities inform these views?

> *"I think science is not related to culture. I do however think that teaching anything can be culturally linked. I don't identify with a culture so much (besides American), so most of the way I teach is American style. I think that this is appropriate because this is America. For students who are not Americans, I have been in their shoes as an exchange student. I think that there are certain jokes or cultural themes that they miss out on, but I think that is literally part of the exchange process. You go to another country for cool opportunities and to learn about another culture. When I am using "American" culture in the classroom, I do try to put a blanket statement out saying that people can believe whatever and retain whatever they want from class, but that it is ok if you don't. I make this statement with evolution because not everyone is the same religion. I think I had a kid say something about black people and sickle cell anemia, so I said that it is more common there based on evolution because sickle cell trait is good for anti-malaria. I then said that there are a few other "races" that have higher proportion of a disease. (lactose intolerance in non- Europeans, cystic fibrosis in whites, and so on…)"* (Writing prompt response, October 19, 2018).

Here, Chad expressly connects culture with race and ethnicity in her conception of how culture relates to teaching and also to science, yet she acknowledges race as a social construct later in her reflection. At this point in the weekly trainings, the TAs were just *beginning to interrogate what is meant by the term culture in relation to science teaching.*

The colonial legacies of settled assumption of what is and isn't science are prevalent in these findings, as is the tension Chad displays by identifying that to her, "science is not related to culture" but yet she continues to discuss the cultural attributes of science in the rest of her reflection.

Bounded Knowledge. One of the key findings for RQ1 was that TAs reacted favorably to utilizing students' funds of knowledge in their instruction. In elementary and secondary science, funds of knowledge pedagogies are typically difficult for teachers to grasp and enact (Upadhyay, 2005). TAs' implementation of funds of knowledge was not because there is some aspect of postsecondary science education makes it easier to do so, in fact, the structure of postsecondary science is prohibitive to incorporating pedagogies such as FoK. Mitch provides an example of how utilizing students' funds of knowledge in his lab was an act of desettling expectations in science, because the boundaries of the lab activity are absolutely constrained by settled expectations of science learning. This text reflects a piece of my analysis for Mitch's funds of knowledge enactment:

> *One of the central components to Mitch's lab was that students engaged in a CURE (Course-based Undergraduate Research Experience) for the duration of the semester in addition to other weekly lab activities. The CURE experiment for these students was predetermined by the BE (Biology Education) department faculty to build on an existing database of research that measures increases/decreases in the Zone of Inhibition – an area in a petri dish that can be used to determine how susceptible a bacteria is to antibiotics – by testing a variety of perishable items of the students' choosing. Mitch encouraged students to bring in their past experiences and household knowledges by asking them to think about their CURE work in relation to their own lives. In introducing the CURE and when explaining that the students had some autonomy to choose their own test items, Mitch asked "does your family – or your household or friends – do*

> *anything specific to keep food from spoiling?" (Weekly Observation, October 12, 2018). This generated a lot of discussion among students about what kinds of foods they knew to grow moldy quickly versus others that seemed to last "for ages" in the refrigerator.*

The CURE project clearly represents the embedded binary of what is considered acceptable knowledge-making in science. What this means is that, while CUREs are designed to provide students with hands on experiences in "doing science," those experiences are bounded by a) faculty research interests and/or support, b) existing data, and c) rigid parameters for exploration. According to postcolonial theory, this is an example of bounded knowledge. Bounded knowledge in the practice of science indicates who hold the power of knowledge and how knowledge is legitimized. In this CURE experience, students are learning an intercultural hierarchy of ways of doing science and engaging in science, and they are also internalizing that in this model of doing science, their forms of knowledge and ways of knowing are both less valuable and do not fit in the larger narrative of science. Mitch had autonomy as a teacher over one portion of the entire lab: what the students were able to use as their experimental variable. This continues the example of bounded knowledge because delimitates what counts as engaging in the process of science. However, Mitch used that opportunity to invite students to make their science learning relational to their household knowledges and experiences. This act helped to reduce slightly the boundaries of acceptable and non-acceptable knowledge in science.

Similarly, Katie utilized funds of knowledge in ways that desettled expectations in science by changing the conditions of learning. Settled expectations refers to "selective appropriations of disciplinary knowledge routinely leave as settled the very knowledge-power relations defined by whiteness that have historically structured and continue to structure inequalities in society, science, and science education" (Bang et al., 2012, p. 315). Therefore, desettling expectations in science requires disrupting those knowledge-power relations.

> *Katie also used funds of knowledge as a tool to build student confidence throughout the semester. Early in the year, and then periodically thereafter, Katie did a writing exercise [a three-minute paper] with students where she prompted them to reflect on what they knew about a given topic. She referred to these writing exercises as them adding to their "knowledge bank" and used their responses to guide her instruction. Additionally, she commented that "having students draw on their previous knowledge of the material gave them more confidence since it proved to themselves that they already know important stuff" (Post-lab interview, September 28, 2018).*

Relating science learning to students' prior knowledge through lived experiences is a hallmark of funds of knowledge pedagogies (González, Moll, & Amanti, 2006). In this example, however, Katie clearly articulates the need for increasing student confidence in their knowledge and validating their knowledge. These key moments pointed toward the importance of desettling the "knowledge-power relations" (Bang et al., 2006) that are widespread in Western science and science education. A key point to make here, however, is that Katie's work – by no fault of her own - is still caught in a movement to superimpose inclusive pedagogies into the dominant discourse of science learning. From a postcolonial perspective, there is an interaction here between the pedagogy of science (the colonizer) and the inclusive or culturally responsive pedagogies (the colonized). In this space, these two pedagogical narratives are in competition which one another to such a degree that one seeks dominance over another. A more postcolonial approach to funds of knowledge would seek to disrupt the colonized pedagogy rather than merely superimpose upon it. This means the act of disrupting settled discourses and pedagogies needs to be intentional, but it also means the settled, colonized aspects of science that created the former pedagogy must also be addressed.

Another key finding of RQ1 was that the TAs engaged in culturally responsive science teaching (CRST) by seeking out opportunities to reduce student anxiety. For example, all TAs made explicit/intentional efforts to make science more accessible to their students. I note this of Chad in my analytic memo:

> *In a similar way, Chad also took extra time to demonstrate difficult techniques or lab processes. While she completed her demonstrations, she pointed out the places in the technique or process that were typical tension points for students. In addition to engaging in this demonstration process prior to the start of every activity, Chad also would pause the lab to review or repeat the demo if she felt that it wasn't going well for students "I want them to feel comfortable doing science – not just learning concepts – and I want them to be ok asking questions and getting things wrong because that's what we do as scientists" (Post-observation interview, October 19, 2018). In the same fashion, Chad called attention to specific concepts that tend to be burdensome for students while she was teaching them. As she did this, she also provided the reasoning for why it's difficult, which made the concept more accessible to students.*

In interrogating the data through a postcolonial lens, I asked: why are there consistent and known tensions for students such that the TAs have to engage in specific anxiety-reduction measures? These tensions are examples of the colonial legacies in science education that continue to legitimize certain knowledge and skills while engaging in the 'Othering' of those who don't fit that mold. For example, stereotypes of whose intelligence is valid have, in my experience, negatively influenced students' self-efficacy in science. This creates an Us/Other binary of who belongs in science. Yet, Chad was careful to make sure students understood that if they didn't quite grasp something the first time, it wasn't a reflection of their intelligence. This speaks to the bounded nature of knowledge in Western science. While this is representative of the student-centered and inclusive teaching aspects of CRST, this is also a critical example of how Chad engaged in desettling expectations in science learning.

In summary of Chapter 4, findings from this study showed that undergraduate biology TAs enact CRST in ways described by four themes: *Funds of Knowledge Connections*, *Differentiating Instruction*, *Intentional Scaffolding*, and *Reducing Student Anxiety.* Additionally, findings supported the following as themes related to what factors influence TAs as they enact CRST: *Affordances, Constraints, TA Beliefs, and TA Identity.* Lastly, a postcolonial critique of the findings revealed that addressing issues of *Settled Assumptions* and *Bounded Knowledge* in science could lead to a decolonized approach to undergraduate science education and, specifically, CRST in undergraduate science spaces.

Chapter 5: Discussion, Implications, and Conclusions

The purpose of this study was to better understand the ways undergraduate biology teaching assistants (TAs) enacted culturally responsive science teaching (CRST), a pedagogical framework that has yet to be formally explored in postsecondary science spaces. Furthermore, the study aimed to explore reasons the TAs shared for their enactments of CRST, as well as provide a postcolonial critique of how Western canonical science and science education contributed to barriers in postsecondary science teaching and learning. In this final chapter, I discuss key implications of this study and identify areas of future research. Given what the TAs demonstrated during the study with respect to CRST as well as the postcolonial interpretation of Western canonical science as an impediment to CRST, I now discuss the implications of this work in five key areas: 1) *developing culturally responsive teaching assistants' funds of knowledge potential, 2) supporting TAs in constructing positive science learning experiences, 3) TA self-efficacy plays an important role in ability to enact CRST, 4) limited autonomy in lab course design impacts CRST enactment,* and *5) colonial legacies in science and science education constrain the impact of CRST.*

Implications for Key Area 1: Developing Culturally Responsive Teaching Assistants' Funds of Knowledge Potential

This study demonstrated that, with targeted supports, biology TAs can enact CRST in undergraduate lab spaces. One of the most salient findings in this study was that TAs embraced funds of knowledge pedagogies as a culturally responsive science teaching (CRST) practice and, in fact, it was one of the most frequent ways they enacted CRST. This finding is particularly remarkable for three reasons. First, funds of knowledge connections are typically difficult for educators to make unless they get to know the communities well (Upadhyay, 2005). Yet as I described in Chapter 3, these TAs, while they had been teaching for at least a year prior to the study, were not embedded in the communities of their students. They instead relied on the trusting relationships they had been cultivating with their students to create spaces to incorporate funds of knowledge connections. For example, when Mitch elicited students' home knowledge about food spoilage, his students were able to engage in conversations about how their experiences were similar and how they diverged (e.g., lemon juice and apple cider vinegar to slow down fruit spoilage). Mitch was then able to build on those interactions. Tanner and Allen (2006) cite the difficulty in making meaningful relationships as a barrier to TAs engaging in inclusive pedagogies, yet these TAs were able to use funds of knowledge pedagogies to create and develop trusting relationships with their students.

Secondly, when observing educators who enact CRST, it is more frequently sociopolitical consciousness connections that tend to be the most accessible for cultivating inclusivity (Brown, Barron, Rozowa, in review). However, for these TAs, sociopolitical connections were routinely part of their teaching, such as when Greg and Mitch encouraged students to engage in science communication writing exercises wherein they drew on their own funds of knowledge to relate a science concept to broader communities. Across all four TAs, they believed that illuminating sociopolitical aspects of science was a critical part of science learning, effectively engaging in the kind of practice of empowerment that described by Suriel & Atwater (2012) to be foundational in creating student agency in science classrooms.

Lastly, TAs utilized funds of knowledge connections in multiple capacities: to engage students in problem solving, to build student confidence, and to make science content and processes relatable. While much research focuses on the ways that TAs are limited in their pedagogical ranges and how we should structure training to meet their perceived lack of ability (DeChenne et al., 2015; Hockings, 2010) these findings indicate that a funds of knowledge approach to CRST broadens the frequency and depth of CRST that TAs engage with. Others have taken such asset-based approaches in K-12 science spaces (Settlage, 2011) while documenting professional growth of preservice teachers.

The implications described above for this key area are important both in science education research and in discipline-based education research where accessible and inclusive undergraduate science education is still in its infancy (Hockings, 2010). Therefore, a warranted area of research would be to continue exploring how to best create TA training and professional development programs that encourage funds of knowledge connections. In this study, those connections were successful and enacted frequently.

Implications for Key Area 2: Supporting TAs in constructing positive science learning experiences

An aspect of CRST is creating safe science learning environments such that students feel empowered to take charge of – or at least engage more with – their own science learning (Calabrese Barton & Tan, 2009). The TAs in this study achieved this by centering their instruction within experiences that contributed to building positive identities in science. For example, each TA strove to make science more accessible to students by creating authentic experiences — such as when Greg challenged students to interpret information from a science writing perspective as well as a science communication perspective. This is of critical importance because I saw a divergence between what the TAs viewed as integral to science learning and how the lab courses were designed to engage students in science. For example, all TAs voiced that engaging students in science process skills and critical thinking was more important at an introductory level than a content-based approach. Furthermore, the TAs expressed that science learning should also focus on real-world issues and they felt that was lacking. Current research in undergraduate science education, however, emphasizes science learning experiences that reinforce discipline-focused and specialized knowledge (Irish, 2013). I would concede that while this is important for upper level, major's science courses, these TAs indicated that a more relational focus in science learning is important to building positive science identities and attitudes. Tanner (2013) advances the field of discipline-based education research by promoting classroom strategies that focus on the "whom" (i.e. student-centered teaching practices) and therefore strive to promote positive learning experiences. However, these such measures of inclusivity do not yet critically address the factors in postsecondary science education that lead to inequitable access to science learning. The TAs noted that it was the content-focused structure of undergraduate science, not the teaching practices alone, that constrained equitable access to science learning for all students.

A fruitful area of future research with respect to cultivating positive science learning environments would be to examine these ideas from a student perspective, beyond solely eliciting the voices of their instructors. The TAs in this study indicated that they felt more interaction and excitement from their students when they engaged them in science learning that was real-world focused and relational. While consistent with what I observed during lab instruction, it would be further beneficial to hear directly from students. Examining what students perceive as effective tools for learning science regarding this finding would be an important addition to this work.

Implications for Key Area 3: Limited autonomy in lab course design impacts CRST enactment

As discussed in previous chapters, the undergraduate biology TAs in my study had limited ability to modify the lab courses they taught. They had control over how they engaged students during the beginning — which was the lecture portion of the lab— and during the lab activity itself, but essentially no voice in what the content and sequence of the course was. This was a concern of the TAs and became an impediment to CRST in each of their contexts. For example, Chad described limited autonomy as prohibiting her ability to differentiate instruction to the degree she felt she needed in order to be culturally responsive to her students whose first language was not English. A wealth of research in TA training has focused on how to get TAs to use active learning strategies (Reeves et al., 2016) but, to date, research has not fully explored how teaching autonomy impacts TAs. An important area of future research would include exploring how building TA agency impacts their CRST enactments.

One of the contributing factors to the autonomy issue is that these were undergraduate TAs with whom I worked, and so complete responsibility of course design would likely have been unrealistic and burdensome (Tanner & Allen, 2004). However, a key implication from these findings is that TA training programs and opportunities should strive to find additional places in the curriculum – and even the departments – wherein TAs have an active voice and can contribute in instructional design. While each

TA voiced various levels of impediment that this lack of autonomy had on their ability to enact CRST, they also described the impact it had on their views of science teaching and learning. This is of critical importance when designing professional developments that focus on culturally responsive science teaching.

Implications for Key Area 4: TA self-efficacy plays an important role in ability to enact CRST

On multiple occasions, all four TA remarked that the design of the weekly trainings was an affordance in the ways they enacted CRST because it helped them to feel more confident in their ability to do so. Specifically, the TAs reflected that engaging in exercise's that scaffolded their own learning was a critical aspect of their self-efficacy in CRST, such as when Katie shared in her post-semester interview regarding her ability to engage in CRST as a result of the training, "I think these views have always shaped my teaching, but now I know how to talk about it from a teaching standpoint" (December 13, 2018).

The training design included how I built on to each week from the previous session as opposed to a series of unconnected trainings. TAs want to know the reasons behind the training concepts, not just how to do them. They also indicated that structured goal-setting was an important part of their ability to feel comfortable enacting CRST, just as Greg suggested when he reflected that the routine goalsetting, practice, and reflection made the act of enacting CRST more fluid to him (Post-lab interview, October 19, 2018). These are important implications because the structure of postsecondary science education – and TA training in those structures – do not share the same theoretical or epistemological orientations as foundational to education research. For example, broadly speaking, science education is grounded in and builds on theoretical frameworks to advance scholarship in the field. Biology education research, on the other hand, a field that has grown considerably in the past decade, lacks the afore mentioned conceptual integration (Talanquer, 2014) but instead is unified in its "evidence-based" (p. 810) approach to science teaching and learning. However, drawing on and engaging TAs in theoretical frameworks (e.g., Vygotsky's scaffolding, critical science agency, pedagogies of empowerment, etc.) was foundational for this CRST training and successful with these TAs.

An important area of future research would be to examine how theories surrounding CRST in K-12 formal educational spaces and science educational spaces can be translated to postsecondary efforts to impact self-efficacy in undergraduate TAs. Furthermore, exploring how to scaffold TA learning would be another area that would greatly contribute to the scholarship of undergraduate science education.

Implications for Key Area 5: Colonial legacies in science and science education constrain the impact of CRST

It was visible across all TAs that some aspects of the structure of their labs were prohibitive to their ability to enact culturally responsive science teaching. For instance, Chad described those barriers through her critique of the rigid power dynamics that exist in undergraduate science education, particularly in relation to whose knowledge counts as valid. My postcolonial critique revealed that colonial legacies are embedded in those structures, which created constraining environments within which the TAs were trying to enact CRST. Carter (2006) and Bang et al. (2012) stress that Western science and science education cannot be the default starting place for how we view what counts as valid knowledge or valid approaches to science teaching. This postcolonial aspect of my study contributes to the process of decolonizing science education in postsecondary spaces. Tuck and Yang (2012) stress, however, that decolonization is not a metaphor. To this end, a warranted area of future research would be to continue exploring the ways in which undergraduate science teaching can challenge the colonized legacies of science by reclaiming educational spaces in a way that disrupts pervasive dichotomies and expands conceptions of 'valid scientific knowledge' such as contributions from Indigenous science and Traditional Ecological Knowledge.

Limitations

For this study, there are two primary limitations, each describe below.

Enactment of CRST at Faculty Level. Collecting and examining similar information surrounding how university faculty engage with CRST would have been an interesting dimension of this work, but outside the scope of this particular study. Potential focus areas for future research could include the beliefs faculty hold about science teaching and learning and CRST, especially in relation to the findings in this study surrounding TA beliefs.

Impacts to Students. While this study contained observational data about student reactions to their TAs use of CRST, further exploration of what exact impacts CRST has on their experiences in the lab outside the purview of my research timeline. A more formal approach to capturing student experiences in the following dimensions would be interesting: student learning and meaning-making, student beliefs about science, and student self-efficacy in science.

Closing Remarks

This study sought to describe what culturally responsive science teaching could look like in postsecondary science by examining the ways undergraduate biology teaching assistants enacted culturally responsive science teaching and the reasons they shared for their enactment decisions, as well critiquing from a postcolonial perspective the ways Western canonical science and science education contributed to barriers in science teaching and learning.

As I have been describing throughout this work, no such contributions to the literature exist, making this study both novel a critical addition to the research surrounding postsecondary science teaching and learning.

Findings from this study showed that undergraduate biology TAs enact CRST in ways described by four themes: *Funds of Knowledge Connections*, *Differentiating Instruction*, *Intentional Scaffolding*, and *Reducing Student Anxiety.* Additionally, findings supported the following as themes related to what factors influence TAs as they enact CRST: *Affordances, Constraints, TA Beliefs, and TA Identity.* Lastly, a postcolonial critique of the findings revealed that addressing issues of *settled assumptions* and *bounded knowledge* in science could lead to a decolonized approach to undergraduate science education and, specifically, CRST in undergraduate science spaces. These findings provide new insights into the ways undergraduate science education might be reimagined to create equitable science learning opportunities for all students.

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APPENDIX A: Expanded Detail of Weekly Training Sessions

Date	Session	Overview of the Training	Connections to Culturally Responsive Science Teaching	Resources Provided	Brainstorming Prompt
September 21, 2018	1	Provided an introduction to how adult students learn. Outlined key findings on adult learning theory including 1) how students' preconceptions about content influence their learning, 2) retrieval of knowledge requires a conceptual framework or "hook" Bransford (1999).	Differentiating instruction as a result of understanding students' pre/misconceptions and/or to create conceptual frameworks can allow multiple ways for students to demonstrate competency and intelligence in the lab (Sternberg, 2004)	Provided TAs with examples of conceptual frameworks and ways to elicit students preconceptions from *How People Learn* (Bransford, 1999)	What are students possible preconceptions about your lab next week? How might you engage their prior knowledge? What steps can you realistically take to do that? What could that "hook" (conceptual framework) look like? How can you work it into your lab? How can you assess if it's working?
September 28, 2018	2	Continued with Bransford's key findings on adult learning, specifically how metacognition can aid in	Equitable science learning spaces provide students with opportunities to develop agency in their learning (Carlone, Haun-Frank, & Webb, 2011) and	Provided TAs a handout that introduced the historical and current scholarly work surrounding accessing	What ways can you help/prompt your students to use metacognition? (you should think about specific points during this next week's lab activities)

		learning. Began introduction to funds of knowledge and how to begin centering personal and student funds of knowledge in instruction.	engaging students in metacognition is a way for them to do so. Validating students' funds of knowledge in the lab can make science learning more accessible to students (Moll et al, 1992).	and drawing up funds of knowledge in science learning spaces.	How do you solve a problem? What are the steps that you take? Why those steps? Identify 2-3 of your funds of knowledge (skills and practices) that have helped you in either your understanding of science and/or your journey as a teacher.
October 5, 2018	3	Continued discussing funds of knowledge in science learning spaces, focusing specifically on how identifying, utilizing, and connecting with students' social and cultural resources "helps a teacher to avoid the pitfalls of an exclusionary" classroom or lab (Upadhyay, 2005, p. 103).	Funds of knowledge connections can transition an potentially exclusionary learning environment into an inclusive space.	Provided TAs with examples of what using students funds of knowledge looks like, including scenarios and strategies (Bouillion & Gomez, 2001)	Specific to your lab next week, what are some ways you can try to elicit students' experiences? Think about how you would ask probing questions and what ways you could integrate their responses into your lesson. Also, how can you intentionally and meaningfully connect your knowledge and experiences to your lesson/teaching next week?

October 12, 2018	4	Building on funds of knowledge, I reiterated the focus on equity in science education and began discussing how identity and students as knowledge producers (Tytler, 2014) is an important aspect of culturally responsive science teaching.	Creating science learning environments where students have opportunities to build positive science identities contributes to inclusive and equitable teaching (Carlone, Haun-Frank & Webb, 2011)	Provided TAs with the Carlone, Haun-Frank & Webb (2011) article as well as Tytler (2014) article.	What does success & competency in science look for you? What do you think success should look like for students in your lab? What does competency in science mean for your students in your lab? What factors do you think influence your students' ideas of success and competency? In what ways can you assess your students' goals & ideas of success/competency? How can you make sure they are attaining their goals?
October 19, 2018	5	Introduced TAs to pedagogical content knowledge (PCK) as a specific aspect of instruction they could focus their culturally responsive	Continued focus on building positive science identities.	Provided TAs with an identity profile assignment to complete but also that they could adapt to elicit more information about their	What topics do you feel the most confident about teaching? In what ways are you confident? Why? In what ways have those topics been challenging for your students in the past?

		teaching efforts if they desired. Continued the conversation about how our identities shape how we teach and how we learn.		students' identities.	*TAs completed an identity profile*: Do any of these identities matter as you're trying to teach? Do any of these identities matter as you're trying to use the culturally responsive/inclusive strategies we've been talking about this semester?
November 2, 2018	6	Continued discussing PCK as a way to examine where the TAs strengths and confidences were surrounding their content and ability to enact culturally responsive science teaching.	General connections to asset-based pedagogies surrounding typically difficult science content.	Provided TAs with specific examples of equitable assessments (Learning Goal Inventory, "Muddiest Point").	For each of these assessments, describe how your PCK informs your decisions about when/where/how to use this kind of metacognitive 'check-in' during your teaching. How do any of your identities inform your PCK? Can describe your views, thus far, on culturally responsive & inclusive teaching? How do any of your identities inform these views?

November 9, 2018	7	Introduction to critical science agency (Basu et al, 2011) and sociopolitical consciousness in science teaching (Mensah, 2011; Powell et al, 2012; Suriel & Atwater, 2012)	Equitable and empowering science teaching can draw upon critical science agency and sociopolitical consciousness to expand and/or deconstruct traditional outcomes in science education (Barton et al, 2011).	Provided students with handouts from chapters of Democratic Science Teaching (Basu, Calabrese-Barton & Tan, 2011)	Broadly speaking in your labs, how can you use science process skills as a way to develop critical science agency? Is there one lab or portion of a lab where this might be easier to accomplish? What do you see as barriers to this?
November 16, 2018	8	Pause for TA reflection and opportunity to engage in their own metacognition.	Drawing on being culturally connected (Esign, 2003) in a broad sense to create inclusive science lab spaces.	Provided TAs with an annotated bibliography of articles from major focal areas of culturally responsive teaching including cultural competence (Ladson-Billings, 1995), critical consciousness (Basu & Calabrese-Barton, 2007), language supports (Luykx & Lee, 2007), social action (Bouillion &	What things do you do routinely that you feel are culturally responsive and/or inclusive? Do you do those things intentionally? Is it part of your beliefs about teaching/learning and/or something that comes more naturally? Describe the things that make up the culture of your lab? Are there culturally

				Gomez, 2001), and care and respectful relationships (Moore-Mensah, 2011)	connected approaches you can make to developing critical science agency? Why do you do this work? Why are you interesting in being inclusive, culturally responsive, etc.? What tools do you need to continue doing this?
November 30, 2018	9	Discussion about learning as a sociocultural and situated process; focus on how students negotiate forms of participations and identities within this process.	Connecting inclusivity in science teaching to empowering student voice in the lab and deconstructing the myth that the teacher/TA is the single knowledge-holder.	Provided students with Bang, Warren, Roseberry & Medin's (2012) work on desettling expectation in science.	What kinds of things collaborations, interactions, engaging, etc. has been most influential through *this* learning process of culturally responsive teaching? What kinds of expectations do your students perceive to exist in your lab? How would you start to (re)frame your labs for next semester given today's

					content? Given the content of the entire semester? What things can you make changes to, broadly speaking? What are some things you might consider doing routinely?
December 6, 2018	10	Closing conversations about culturally responsive science teaching and how TAs view themselves as science educators.		Provided TAs with examples of what culturally responsive science teaching looks like when specifically responsive to a particular group (i.e. Minnesota Native Americans).	To whom is your instruction culturally responsive? Whose voices matter and are heard? Who holds the power?

APPENDIX B: Example of Observation Field Notes

Date: 11/15/18
Teaching Assistant Name: Mitch

Focus Area		**Notes**
I. General Culturally Responsive Connections	**A. Multiple Ways to Demonstrate Competency & Intelligence**	
	d. Do TAs provide ways for students to draw on their "cultural capital" when solving problems?	
	e. Does the TA provide scaffolds to allow for varying levels of discourse ability?	Mitch has done this all semester – keep reviewing other labs – but today he achieved this by scaffolding the students' self-efficacy in their own knowledge by providing constructive feedback on their work and then reviewing with them the salient aspects of his feedback ++ also building up the things they did well/right
	f. Do TAs create spaces where students' ways of knowing are validated in the lab/classroom?	Mitch continues to give students room to act as leaders and experts in their work – this reflects to me that he is validated what they know and how they know it (see below for various times when he does this)
	B. Multiple Ways to Achieve Success	
	d. Do students have opportunities to engage in collaborations and take on various roles?	As above, students get to be the experts in Mitch's lab often
	e. Can the students utilize and/or build on their	

	identities as experts/teachers during lab/class activities?	
	f. Can students access and/or explain science content, concepts, and/or processes in their home or dominant discourse?	
	C. Science Experiences are Rigorous	
	b. Do TAs uphold rigorous science experiences in lab/class for all students?	Mitch keeps the academic/scientific rigor at a consistently high level and this is evident every week. This week, it is clear that because he makes efforts to get to know *all* of his students well, he is able to maintain rigor for all students equally as well
II. Funds of Knowledges Connections	**A. Diverse Knowledge and Perspectives**	
	b. Are students' home and community funds of knowledge utilized and validated in the lab/classroom?	Keep reviewing Mitch's reflections for this – he incorporates aspects of students' FoK nearly every week, even if in a small way
	B. Positive Science Identities	
	b. Do classroom or lab in scientific engagement allow students to express their own views and beliefs about what scientists are and look like?	
III. Sociopolitical Consciousness Connections	**A. Drawing on local/regional/community-based problems**	
	b. Can students develop awareness of local, regional, or community issues and develop decision-making skills action by doing so?	Mitch created this additional focus for the public service announcement assignment that is clearly connected to SPC

Field Notes:

M has students go into their reflection assignment on Canvas so they can see his feedback on their writing

Quoting Mitch:
"*take 5 minutes, and what feedback that I gave you that you're comfortable sharing, share with your partner and get feedback from me that maybe I didn't leave for you specifically, but I left for someone else and it's broadly applicable*"

He asks what comments are you hearing often?

Students say grammatical things – M: "*which is good because those are easy to fix*"

Students ask how in depth should a title be for the graph? M: "*it should really tell me what the data is –whole goal is to not be vague*"

Announcements
Upcoming Deadlines

3rd major lab quiz – evolution/keystone predator lab (like a pre-lab quiz)

Below are continued announcements Mitch gives students, watch for how Mitch is helping his students demonstrate science process skills through writing exercises:

- Paper logistics (not giving you a page limit, but students who have gotten good grades – 2 pages single spaced) – "*you all have the rubric for the paper*"

- On the Reflection: "*how many of you took a jr or sr writing class in high school, but you probably heard the phrase show vs. tell the story"*

- *"Almost all of you had overly long methods – for the paper, shorten it to about a paragraph"*

- "*Address the directionality of the hypothesis – for final paper, it needs to go a little bit further. For example, why it's showing a zone of inhibition and the size/direction of the effect. Justify which compound will produce the largest ZoI and why"*

- "I don't like a narrative structure – aim for a formal writing style with an important idea that will bring the reader in; you don't need to present your lab in a chronological fashion"

Conclusions are hard! (see this slide & review this part of the lecture again)

Discussion of error – move away from human sources of error – more aim for stuff that even if you did this really well, even if you had a enough, what's the <u>flaw in your plan</u>

(perishable things sitting out of refrigeration for 4 weeks); so future directions aren't just --- we got this conclusion, so what are we going to do next? A novel experiment that builds on the work we've done so far (new and different experiment building off the experiment you already did)

M says he changed the PSA objectives -- ~18:00 this is a critical moment for Mitch's CRST

Quoting from Mitch:
"*Aim higher" --- look at a case study of why your research might matter – using primary literature or some other sort of reliable evidence, find a community that has a health disparity that would benefit from a public health intervention based on your research. The scale is up to you: could be all of the dentists in America, a country, a town, a community that has need of or could benefit from your research in a passionate and creative way – you are an outsider, not presenting as though you know everything. Do you see how this will lead us to have a more fruitful conversation? And this is the best example of why we do science*."

Next students take a 5-minute evolution quiz

Quoting Mitch:
"And that's all the time for this -- and now you never have to do a pre-lab quiz again!"

Mitch goes over Evolutionary terms –

From his slides/lecture:
Evolution is not directional – human aren't the most evolved species on earth – for example, tapeworms don't have a brain, etc. but there are more tapeworms than humans – they are very evolved/successful --- fish do not evolve into reptiles as an effort to get onto land, that just happened ---- evolution acts on heritable traits, not acquired ones [look at these slides again] fixation is when we lose an allele completely

1) Natural selection
2) Genetic drift (hard to explain but we're going to demonstrate it today in lab)
3) Mutation
4) Gene flow or migration

Then Mitch gets students ready to complete the evolution lab, quoting from Mitch:
"I'm not going to tell you how to flip pennies, but if I was going to tell you how to flip pennies" – students and Mitch chuckle and then tells them how is the most effective/efficient way to complete the activity

Mitch goes around to all of the groups/pairs as they are working through the lab and answers questions and checks in (he has to repeat "*the excel file is on the desktop that you can use to graph"* a lot but never a change in tone or patience)

Mitch pauses the lab to call attention to an issue that keeps coming up for students, quoting Mitch:
"Everybody, focus, focus – evolution only occurs on a population scale, not on an individual scale, I will ask you that question on a major lab quiz, I promise"

"In the next 2-4 minutes, your goal is to move on to the allele stuff, finish up your EvoDots"

This is something M does in every lab, he keeps them on task for every activity

Mitch calls attention to confusing issue, quoting M:
"I'm going to take your attention one more time to talk about this because it's a little confusing – look at the frequency of Allele A1, Allele A2. The blue line opposite of the red line --- you'll never really see the blue line, but you can intuit that it exists."

"Who things A1 is dominate?" [one or two raise their hand]
"Who thinks A2 is dominate?" [a few raise their hands]
"Who is not going to guess right now because you're kind of afraid?" [most of the class raises their hand and some of them are chuckling]

Mitch talks through with individual pairs/groups about what things impact fitness and why they would or wouldn't impact fitness

Question to the class; is it possible that 2 genotypes have the same fitness values? I wanna see 2 hands up – "ok, let's go with 4!" Students gives an answer and he builds on that
"Ok Katie: she says: not everyone has babies so it will rise and fall – M: "interesting, I've never heard that before, but yes – because not everyone is trying to have babies equally hard (~1:05:00) "any other ideas or are we feeling good about that question" so then they move on to the next thing ("keep it up, you guys are doing great")

"If the A1 & A2 are confusing for you, just call them heads and tails – that's fine"

"I'm going to distract you from your pennies – checkpoint, is there evidence of this population evolving? Is the population becoming better suited to its environment? What conclusions can we make about if human populations are evolving? "let's think about the fact that we get new alleles in our populations in fetuses in diseases that kill them in utero, for example – those alleles are quickly selected against – evolution isn't always 'we grew a tail'"

When students are either done early or slacking off, M goes around and asks them probing questions "*so what questions did you have about allele frequency*" and then is referring them to a graph example he made [see Pic] *("more genetic diversity in larger populations – so why would genetic drift be more intense in smaller habitats*" he asks and "*why would natural selection allow more alleles to exist in a bigger population, why would natural selection…in a smaller population?"*

He says things/asks questions in multiple ways in case the concept isn't clear or if he senses that they aren't getting it – he also does this if it seems like they reached the answer super quick, so he uses it as a probing/digging deeper mechanism

"*Why, in a smaller habitat, would one of these types of evolution remove alleles more? Why would they be more intense in small habitats*" some students provide answers and discussion

"I need somebody to make that leap – why would a small habitat size lead to more genetic drift?" –student answers
"ok I feel really good about that answer"

M wraps up:
If I have a huge plot of land, like Yosemite National Park – and maybe if we're looking at darker/lighter bunnies – nat. selection keeps light (more niches in a big habitat) Vs. smaller habitat, less niches, i.e. the mall here on campus – Big issues here in MN/WI – unhappy unhealthy population / roads/

"Do you feel good about evolution? Did you learn something today about evolution?"

APPENDIX C: Weekly Writing and Brainstorming Prompts

Date	Session	Brainstorming Prompt
September 21, 2018	1	What are students possible preconceptions about your lab next week? How might you engage their prior knowledge? What steps can you realistically take to do that? What could that "hook" (conceptual framework) look like? How can you work it into your lab? How can you assess if it's working?
September 28, 2018	2	What ways can you help/prompt your students to use metacognition? (you should think about specific points during this next week's lab activities) How do you solve a problem? What are the steps that you take? Why those steps? Identify 2-3 of your funds of knowledge (skills and practices) that have helped you in either your understanding of science and/or your journey as a teacher.
October 5, 2018	3	Specific to your lab next week, what are some ways you can try to elicit students' experiences? Think about how you would ask probing questions and what ways you could integrate their responses into your lesson. Also, how can you intentionally and meaningfully connect your knowledge and experiences to your lesson/teaching next week?
October 12, 2018	4	What does success & competency in science look for you? What do you think success should look like for students in your lab? What does competency in science mean for your students in your lab? What factors do you think influence your students' ideas of success and competency? In what ways can you assess your students' goals & ideas of success/competency? How can you make sure they are attaining their goals?
October 19, 2018	5	What topics do you feel the most confident about teaching? In what ways are you confident? Why? In what ways have those topics been challenging for your students in the past?

		TAs completed an identity profile: Do any of these identities matter as you're trying to teach? Do any of these identities matter as you're trying to use the culturally responsive/inclusive strategies we've been talking about this semester?
November 2, 2018	6	For each of these assessments, describe how your PCK informs your decisions about when/where/how to use this kind of metacognitive 'check-in' during your teaching. How do any of your identities inform your PCK? Can describe your views, thus far, on culturally responsive & inclusive teaching? How do any of your identities inform these views?
November 9, 2018	7	Broadly speaking in your labs, how can you use science process skills as a way to develop critical science agency? Is there one lab or portion of a lab where this might be easier to accomplish? What do you see as barriers to this?
November 16, 2018	8	What things do you do routinely that you feel are culturally responsive and/or inclusive? Do you do those things intentionally? Is it part of your beliefs about teaching/learning and/or something that comes more naturally? Describe the things that make up the culture of your lab? Are there culturally connected approaches you can make to developing critical science agency? Why do you do this work? Why are you interesting in being inclusive, culturally responsive, etc.?

		What tools do you need to continue doing this?
November 30, 2018	9	What kinds of things collaborations, interactions, engaging, etc. has been most influential through *this* learning process of culturally responsive teaching? What kinds of expectations do your students perceive to exist in your lab? How would you start to (re)frame your labs for next semester given today's content? Given the content of the entire semester? What things can you make changes to, broadly speaking? What are some things you might consider doing routinely?
December 6, 2018	10	To whom is your instruction culturally responsive? Whose voices matter and are heard? Who holds the power?

Appendix D: Code Book

<u>*Research Question 1*</u>
Added a reflection activity for student metacognition
Added class learning objectives for students to see every day
Added prompt for engaging students to relate content to their own lives
Addressed possible biases
Allowing students to act as experts
Amplifies students' correct answers
Asked probing and clarifying questions
Asked students to talk with each other to determine best answers
Asks for student feedback on teaching
Asks probing questions to ensure content understanding
Assigned students specific roles in lab
Assigning student the role of expert
Assigns roles for each student in the group
Assigns specific roles
Avoided putting students on the spot
Avoided simply giving out answers to student questions
Brought in students' past experiences and knowledge
Build student confidence by allowing exemplars to share
Builds confidence by making it OK to be wrong
Builds inclusive atmosphere by maintaining eye contact
Builds inclusivity by using students' names immediately in the semester
Builds on one on one interactions with students or groups to reiterate a concept
Builds student agency by encouraging them to self-assign roles
Builds student confidence by articulating that a concept is difficult
Builds student confidence by doing confidence checks
Builds student confidence by highlighting exemplars
Builds student confidence by pointing out positive/right things in addition to what they got wrong
Builds student confidence by reviewing complicated lab procedure steps routinely
Builds student self confidence by building on their dialogue or interaction
Builds student self confidence by encourages group interaction
Builds students' self confidence by building on their correct answers
Built on previous week's materials to scaffold understanding
Calls on each student by name consistently
Challenged students to think independently about difficult content
Challenged students to work together to solve difficult problems
Changes gears on the spot to reduce student anxiety
Circulated the room to talk to all students
Created additional instructions to scaffold lab process and content
Created an easygoing atmosphere by participating in lab activities

Created opportunities for student ownership of tasks
Creates a safe learning atmosphere by providing low stakes assessments and activities
Creates inclusive relationship by offering email as a way to communicate confusion
Defuses uncomfortable lab material/content
Demonstrated challenging lab practices before student trials
Demonstrated multiple examples for a particular concept
Demonstrates accessibility to students
Demonstrates information in a variety of ways
Demonstrating that science can be hard for everyone and that's ok
Differentiated instruction on the spot
Differentiates instruction in multiple ways during a single teaching segment
Diffused feelings of awkwardness
Discussed the importance of learning a particular concept
Displayed exemplar student or group work to entire class
Drawing on students previous or existing knowledge
Drawing on students' interests to build relationships
Edited pre-made slides to include more examples of specific content
Elicited answers and interaction from all students
Elicited conversation from all students
Elicited information from all students
Elicited information from students
Emphasizes a point by physically demonstrating what they are saying
Emphasizes important concept by differentiating instruction
Encourage students to relate learned material to personal lives
Encouraged group participation
Encouraged students to reflect on their own experiences in relation to content
Encouraged students to rely on one another
Encouraged students to shape their own learning experiences
Encourages confidence in content or process understanding by having students act as experts
Encourages critical thinking
Encourages critical thinking and science process skills
Encourages student interaction
Encourages student interaction in groups and pairs
Encourages student interaction through group or pairs
Encourages students to bring in relavent real world scenarios
Encourages students to connect content to their lived experiences
Encourages students to relate content to themselves
Engaged all students
Engaged more student interactions through group work
Engaged students through promoting participation
Engages and builds on students prior knowledge
Engages student interaction through brainstorming
Engages student metacognition to determine confidence
Engages students by asking them a lot of questions

Engages students by consistently interacting with them throughout entire lab
Engages students prior knowledge
Engages students through group interaction
Ensure content understanding by also explaining what is not correct
Ensure content understanding by debriefing the lab at the end
Ensure content understanding by doing large group check-in
Ensure content understanding by reiterating reasons for right or wrong answers
Ensured multiple students had opportunities to talk
Ensures content understanding by constantly checking to see if students are on the same page
Ensures content understanding by elaborating on students' correct answers
Ensures content understanding by explaining why a given answer is right or wrong
Ensures content understanding by using a science process to illustrate answers to questions
Ensuring content understanding
Ensuring everyone presented portions of the lab
Explains to students the reasons for choosing certain teaching or organizational strategies
Explicit attempt to build student agency
Formulated learning goal specific to CRST ahead of time
Frequently uses students' names
Gauged student learning by asking about their confidence in content understanding
Gave student feedback to write testable research questions
Getting students to volunteer information and conversation
Gauged students' understanding often
Illustrates answers to student questions in variety of ways
Included more active participation from students
Incorporated methods for different learning styles in instructions
Incorporated students' interests into CURE lab
Intentional attempts to build student confidence
Invites students to relates content to their relatives
Keeps students and groups on task
Kept students collectively at similar paces
Made intentional attempts to make students feel comfortable
Maintained expectations of rigor
Maintaining high expectations and scientific rigor
Maintaining student engagement
Maintains rigorous scientific norms
Makes connections to students' prior knowledge
Makes science relatable by pointing out the human error or flaw and making it OK
Making sure students understood lab procedure
Monitors student confidence in their understanding of content or process
Personalizes slides with memes and thoughts of the day
Prompts students to relate content to real life
Provided opportunities for students to complete lab work collectively
Provided ways for students to build confidence

Reduced student nervousness about exam by limiting time spent on other things before exam
Reduces anxiety by addressing known areas of confusion
Reduces anxiety by describing difficulty content as causing common questions
Reduces anxiety by providing weekly updates and reminders about schedule/assignments
Reduces student anxiety by having helpful hints slide
Reduces student anxiety by making it OK to be wrong
Reinforces concepts by having students apply them directly after talking about them
Relates content to real life
Relates content to real life scenarios
Relates lab content to class content consistently
Relationship building through one on one conversations with students
Scaffolds difficult content
Scaffolds lab processes by reviewing steps from previous week
Scaffolds material by using a slide of main points thus far
Shared students' successes with the entire class
Switched teaching techniques when students didn't understand something
Talking to students one on one to build student self confidence
Tried new strategies for making lab feel more inclusive
Tried using more interactive lecture techniques
Used a learning goal as mechanism for student to deepen content understanding
Used humor to lessen student feelings of awkwardness
Used more objective terminology for typically uncomfortable topics
Used multiple modes of displaying information
Used personable examples to make himself as TA more approachable
Used personal examples to make science more approachable
Used personal experienced about the subject to have a broader conversation
Used real life comparison/analogy to clarify confusion
Used specific instructional strategy to make sure everyone was on the same page
Used strategies for reducing student anxiety
Uses extensive strategies to make lab space inclusive and comfortable
Uses group discussion to build student engagement
Uses humor as a community building tool
Uses humor to build a lab culture where students feel more at ease
Uses humor to create a light-hearted atmosphere
Uses humor to create inclusive atmosphere
Uses humor to describe an otherwise dry process
Uses humor to encourage student participation or engagement
Uses humor to engage students
Uses humor to prompt student interaction
Uses innovative and unique pedagogical tactic
Uses lab space as a way to build students' confidence for more high stakes aspects of class
Uses multiple hands multiple voices easy assessment technique
Uses multiple modes of instruction to make a point or clarify a concept

Uses multiple ways of differentiating instruction
Uses multiple ways to demonstrate content
Uses personal example to reiterate a concept
Uses personal experiences to relate content to real life
Uses personal relevancy to illustrate a concept
Uses personalized slides to create fun atmosphere
Uses probing questions to build critical thinking skills
Uses probing questions to elicit student engagement
Uses probing questions to ensure content or process understanding
Uses real life examples for why science is important
Uses real life examples to illustrate a concept
Uses real life issues to engage students in argumentation
Uses real world analogy to reiterate a concept
Uses regional and local examples to illustrate a concept
Uses relevant examples often to reiterate or emphasize a concept
Uses small group interaction as teaching tool for larger group
Uses student metacognition
Uses think pair share
Uses throat vote easy assessment
Using an easy assessment technique
Using other students' exemplar work for students to examine
Validates students' knowledge
Waiting for all students to have a chance to ask questions
Waiting for all students to have chance to ask questions
Walked around the lab to talk to all students

Research Question 2

Being personable helps with small groups
Building trusting relationships with students pays off
Checking in with students one on one
CRST activities didn't take long to implement
CRST activities didn't take long to prepare ahead of time
CRST activities were easy to implement
CRST activities were straightforward
CRST takes practice
Developing things from scratch
Didn't feel as rushed
Easier when ta written lab because no worry of getting in trouble
Experiment or process was simple so easier to try CRST
Face pace of the lab
Feeling awkward
Feeling awkward projected to students

Freedom of lab makes CRST easier
Getting to know the students helps ta and student in CRST
Group discussions allow ta to see where confusion is
Group participation is more rewarding when students are confident talking
Hard to balance level of detail with polarized prior knowledge
Hard to gauge if it's working for students on the spot
Harder to teach broad concepts
Have more to learn
Having more time
Interactional labs are easier to do CRST in
Is personable
Keeping similar or same student groups helped
Knew a lot of outside and relevant information ahead of time
Know the strategies of CRST
Knowing evidence based CRST strategies
Knowing outside info made easier to relate it to students
Knowing students helps to make lessons interesting
Lab design of lecture and quiz after
Learning how to do CRST makes it less awkward
Learning how to gauge students responses to a CRST activity
Lesson easier to try CRST because taught many times before
Limited time
Limited time makes activities rushes
Lots of time makes it easier
Multiple groups or students at different time points in lab activity
No autonomy makes any pedagogical innovation difficult
No autonomy makes CRST difficult
No autonomy over lab priorities
No autonomy to modify lab content
Not enough time to make sure content understanding and fitting all activities in
Not enough time to make sure everyone understands the material
Not feeling like a CRST expert
Not having autonomy over the lab or activity design
One on one conversations take time and time is limited
Open-ended exploration activities
Preplanning helped try new things out
Repeating CRST strategies make it easier each time
Rushing helped students stay motivated

Same student groups builds community among students
Same student groups makes working together smoother
Small class sizes
Student really knowing the ta helps them accept when ta gives instructions
Students came to class prepared
Students don't learn about experiment or process ahead of time
Students entered lab with prior procedural knowledge
Students get more confident talking to each other over time
Students get more confident talking to ta over time
Students having repetitious exposure to material ahead of time
Students respect the ta
Students trust ta
Students voice confusion more when confident talking to ta
Switching groups for equity is hard in small class
TA enthusiasm for the lab
TA knowing students really well
TA less intimidated to try CRST with small class
TA loving the subject and course
TA really liked the lab content
TA written or designed labs are easier to incorporate CRST in
Take time to make sure students on same page
Technical nature of the lab
Time
Time is always a major constraint
Time limited because labs are jam packed
Time made it more difficult
Time was a really big challenge
Too many activities and not enough depth into material
Understanding students' prior knowledge on the subject
When CRST strategy depends on student engagement
When everyone is more comfortable with each other
When student prior knowledge is polarized

APPENDIX E: Institutional Review Board (IRB) Documents

Study Approval Notification

From: ethosirb@umn.edu
Subject: STUDY00004834 has been approved
Date: November 9, 2018 at 3:03 PM
To: fult0050@umn.edu

Template:IRB_T_Post-Review_Approved

Notification of Approval

To:	Hillary Barron
Link:	STUDY00004834
P.I.:	Julie Brown
Title:	Culturally Responsive Undergraduate Science Education
Description:	This submission has been approved. You can access the correspondence letter using the following link:

Correspondence_for_STUDY00004834.pdf(0.02)

To review additional details, click the link above to access the project workspace.

Copy of Recruitment Document

Pre-Consent and Sign-Up

Advancing Equitable Science Education through Training for Culturally Responsive Science Teaching

Procedures
You will participate in 10 trainings related to culturally responsive science teaching, each will last approximately 30 minutes. The goals of these trainings are to give you strategies to incorporate in your labs/classrooms. Your reflections will be invaluable to the study. Also, I will observe you as you enact these strategies and will conduct brief interviews with you.

Compensation
You will receive a stipend of $100 at the end of the Fall 2018 semester.

Confidentiality
The records of this study will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify a subject. Research records will be stored securely and only researchers will have access to the records. Study data will be encrypted according to current University policy for protection of confidentiality. Videotapes will only be accessible to the project staff and will be secured on a password protected university server.

Questions
If you have any questions or concerns, please email me, Hillary Barron, at: fult0050@umn.edu

Please **print** your name and your email if you are interested in participating in this study:

Name	Email

Copy of Email Invitation to Teaching Assistants

Hello Teaching Assistants!

I am writing to invite you to participate in additional teaching trainings this semester that focus more deeply on how to utilize culturally responsive and inclusive teaching practices in your biology labs. These trainings are being conducted as part of a research project to better understand how teaching assistants can enact these teaching practices. Below you will find the procedures and compensation outlined. If you would like to be part of this study, please reply to my email and I will contact you shortly to discuss the details.

Procedures
You will participate in 10 trainings related to culturally responsive science teaching, each will last approximately 30 minutes. The goals of these trainings are to give you strategies to incorporate in your labs. Your reflections will be invaluable to the study. Also, I will observe you as you enact these strategies and will conduct brief interviews with you.

Compensation
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Questions
If you have any questions or concerns, please email me, Hillary Barron, at: fult0050@umn.edu

Thank you,
Hillary

Hillary A. Barron
PhD Candidate, Science Education
Graduate Research Assistant, Biology Teaching and Learning
University of Minnesota
Phone: 218.428.2689
Email: fult0050@umn.edu

CONSENT FORM

Advancing Equitable Science Education through Training for Culturally Responsive Science Teaching

You are invited to be in a research study that investigates the development of culturally responsive science instruction and inclusive teaching practices in undergraduate science within a semester-long mentoring and training program for experienced teaching assistants (>1 semester teaching). You were selected as a possible participant because you have been a teaching assistant for at least one semester prior to Fall 2018. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

This study is being conducted by: Hillary Barron, PhD Candidate in Science Education and Graduate Research Assistant in Biology Teaching and Learning.

Background Information:

The purpose of this study is: to explore how teaching assistants enact culturally responsive and inclusive science teaching practices and the reasons they share for doing so (or not enacting).

Procedures:

You will participate in 10 trainings related to culturally responsive science teaching, each will last approximately 30 minutes. The goals of these trainings are to give you strategies to incorporate in your labs/classrooms. Your reflections will be invaluable to the study. Also, I will observe you as you enact these strategies and will conduct brief interviews with you. Our training sessions and interviews will be video/audio recorded.

Risks and Benefits of being in the Study:

The study has potential risks: As a teaching assistant you may be uncomfortable being observed in your classroom.

The benefits to participation are: an opportunity to receive feedback and mentoring on your teaching and learn equitable teaching practices.

Compensation:

You will receive payment: a stipend of $100 will be disbursed to you at the end of the Fall 2018 semester

Confidentiality:

The records of this study will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify a subject. Research records will be stored securely and only researchers will have access to the records. Study data will be encrypted according to current University policy for protection of confidentiality. Videotapes will only be accessible to the project staff and will be secured on a password protected university server.

Voluntary Nature of the Study:

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

Contacts and Questions:

The researchers conducting this study are: Hillary Barron. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact them at 218-428-2689, fult0050@umn.edu.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), **you are encouraged** to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

You will be given a copy of this information to keep for your records.

Statement of Consent:

I have read the above information. I have asked questions and have received answers. I consent to participate in the study.

Signature:____ Date: __________________

Signature of Investigator:____ Date:
____