From Professional Development to Pedagogy: An Examination of Computer Science Teachers' Culturally Responsive Instructional Practices

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Abstract: The field of computer science continues to lack diverse representation from women and racially minoritized individuals. One way to address the discrepancies in representation is through systematic changes in computer science education from a young age. Pedagogical and instructional changes are needed to promote meaningful and equitable learning that engage students with rigorous and inclusive curricula. We developed an equity-focused professional development program for teachers that promotes culturally responsive pedagogy in the context of computer science education. This paper provides an overview of our culturally responsive frameworks and an examination of how teachers conceptualized and integrated culturally responsive pedagogy in their classrooms. Findings revealed that teachers were consistently planning to implement a wide range of culturally responsive instructional and pedagogical practices into their classrooms.

Introduction

A major challenge within the discipline of computer science (CS) is recruiting and retaining women and minoritized individuals to the field (Cuny, 2012). The under-representation of females and minoritized groups in computing poses a significant equity issue because CS knowledge and skills enable students to create and innovate, develop a sense of competency that may lead to further pursuits in computing, and eventually take advantage of the growing high-paid career opportunities in computing-related fields (Google, 2014; Google & Gallup, 2015). While there are many explanations for the discrepancies in representation, the most pressing is a result of culturally irrelevant CS education (Scott & White, 2013). One way to contour teaching practices to engage diverse learners is through professional development (PD) that prepares teachers to integrate culturally relevant pedagogy (CRP) into existing school curricula. CRP enables effective teaching, meaningful learning, and equitable learning environments (Gay, 2018; Ladson-Billings, 1995a). However, teachers' perceptions of their culturally responsive practices are often not aligned with their classroom instruction (Debnam et al., 2015). Self-reflection is an essential practice that requires educators to acknowledge their biases and positionality when attempting to integrate CRP into their teaching (Borrero et al., 2018). Only then can teachers authentically represent and harness students' cultural assets in their classrooms (Kohli, 2012).

Our work seeks to address the underrepresentation of minoritized groups in CS by utilizing culturally responsive frameworks that integrate knowledge relevant to youth identities and communities with computational learning activities (Authors, 2019; Ladson-Billings, 1995b; Nieto, 2002). Specifically, we seek to answer two research questions:

1. How do teachers conceptualize and plan to apply CRP in their classrooms while attending an equity-focused CS PD program?

2. In what ways do teachers apply tenets of CRP in their pedagogy and lesson planning following their participation in an equity-focused CS PD?

Literature Review

Elements of Effective PD

PD is widely considered as a critical element in the implementation of new standards and curricula (Darling-Hammond et al., 2009; Desimone, 2009). To date, there is substantial evidence that effective PD is characterized by five key elements: focus on content, active learning, coherence, collaboration, and sustained duration (Desimone, 2009). Clearly, PD must provide teachers with opportunities to strengthen their knowledge of content and how to teach it. Knowledge of content is critical in CS where teachers have not typically studied this content in their teacher preparation and thus need opportunities to deepen their knowledge as well as pedagogical techniques (Century et al., 2013; Margolis et al., 2017). To foster teacher learning, PD should include active learning strategies, such as opportunities to observe, analyze student work, and make presentations (Desimone & Garet, 2015). Further, active learning strategies engage teachers in designing and practicing curricula activities that will help build student engagement while providing opportunities for continuous reflection about teaching (Darling-Hammond et al., 2009; Powell et al., 2010). In all instances, PD should be coherent by helping teachers connect the materials they are expected to teach to their district and school plans while considering the needs of their students (Desimone & Garet, 2015). Specific to CS, it is important to help teachers understand how big ideas of CS could be integrated with core curricular content, so they can more easily apply learning from PD into their lessons.

In terms of structure, quality PD needs to support collaboration, be of sufficient duration, and provide follow-up support. Collaboration is particularly important for teachers of CS who are often singletons in their school with no colleagues with whom to share experiences (Yadav et al., 2015). Finally, effective PD extends learning over multiple days for at least 20 hours or more and provides follow-up support (Desimone & Garet, 2015). Follow-up support is important in the field of CS both as a means for overcoming teacher isolation, but also as a way of providing job-embedded assistance in a field that constantly advances (Margolis et al., 2017).

While there is wide recognition that the above elements are essential in supporting teacher learning, there is scarce research on how to apply them in the design of effective PD in computing (Menekse, 2015). Although CS curricula and accompanied PD have been heavily promoted in recent years through initiatives such as *CS for All*, relatively still little is known about how teachers can support CS education in formal school settings (Goode, Skorodinsky et al., 2020). Specifically, an extended literature review conducted by Menekse (2015) uncovered just 21 studies related to PD in CS. Importantly, Menekse's review found that the majority of the CS PD efforts were not consistent with principles of high-quality PD reported in the literature (see Desimone, 2009); they lasted one week or less, did not provide follow-up support, did not include active learning strategies, and did not explicitly address pedagogy for teaching CS.

Most of the CS PD programs offered to date were designed by higher education institutions to support popular CS curricula, such as Exploring Computer Science (ECS; Goode et al, 2012) or Mobile Computer Science Principles (Mobile CSP; Morelli et al., 2016). Such programs are intended primarily for teachers teaching stand-alone CS curricula and do not involve teachers at the elementary or middle school level interested in integrating principles of computing in content-area curricula. Other PD programs were launched by prominent organizations that provide K-12 curricula to schools, such as Code.org, Project Lead the Way,

and Google (Delyser et al., 2018; Menekse, 2015). Although these programs include teachers across K-12, they also focus on the implementation of specific stand-alone curricula developed by the aforementioned organizations. While these programs have been beneficial in supporting both novice and experienced teachers, in some cases (e.g., Project Lead the Way) they require extensive financial resources which further accentuate equity considerations for school systems serving high percentages of minoritized students (Franklin et al., 2020). As a result, more work is still needed in the design, implementation, and research of high-quality PD programs that help teachers implement rigorous and inclusive CS instruction connected to core content area curricula at no cost (Goode, Skorodinsky, et al., 2020). In this work, we present one effort that supports teachers towards this goal.

Equity Focused Professional Development in Computing

According to recent data, only 16% of teachers view themselves as well-prepared to incorporate students' cultural backgrounds into CS instruction (Gordon & Heck, 2019). Yet, equity is not typically at the center of PD programs focusing on CS (Goode, Ivey et al., 2020). As CS continues to become an integral part of school curricula across the U.S., it becomes necessary to help teachers address their own biases of who can be successful in computing, and develop knowledge and skills needed to incorporate equitable practices rooted in CRP into their instruction (Goode, Ivey et al., 2020). As a result, CS PD programs should move beyond a focus on CS content and pedagogy to explicitly incorporate issues of equity that help address the long-standing underrepresentation of minoritized students in computing.

One of the most widely researched CS PD programs with an explicit focus on equity is associated with the ECS curriculum first launched in the Los Angeles Unified School District (LAUSD), which was designed with the overall intent of broadening participation in computing for females and students of color (Margolis et al., 2014). The ECS curriculum integrates CS content with computational practices and is designed to introduce students to computing ideas rather than specific programming languages (Goode et al., 2012). The ECS PD format provides an intensive learning experience for teachers over a 2-year period that helps develop both the content and pedagogy knowledge needed to engage *all* students in learning the ECS materials. Finally, the ECS program encourages teachers to develop habits of reflection that allows them to examine their pedagogy and the ways it influences student learning, particularly for underrepresented populations (Goode et al., 2012).

In more recent work, Goode, Ivey et al., (2020), examined how teachers engage in learning about race and equity in the context of a summer week-long PD program associated with the ECS curriculum. During the week, teachers experienced CS concepts, inquiry oriented practices, and curricular lessons focusing on race and cultural knowledge in CS. Data were collected from 94 teacher participants through field notes capturing how teachers talked to each other about race and surveys focusing on teacher beliefs about equity, race, and CS over the course of their participation in PD. Findings indicated that teachers developed a sense of urgency to broaden participation in computing as well a sense of agency to disrupt inequities in CS among underrepresented populations. Further, they developed beliefs and instructional skills that support equity teaching in CS. More studies like this are needed to help teachers learn about equitable pedagogical practices that utilize student cultural backgrounds to broaden participation in computing. In this work, we present a PD approach that helps teachers move towards this goal, by examining their own beliefs and using tenets of CRP to help embrace their responsibility in disrupting inequities in CS.

Context of this Work

This work is situated in a larger effort to improve the teaching of computing in the U.S. through a three-pronged approach: teacher professional development, a college field-experience course, and sustainable school partnerships (Authors, 2015). In this work, we focus explicitly on our approach to teacher PD, designed and delivered by the authors. Consistent with characteristics of effective PD, our program incorporates a two-tiered approach to supporting teachers as they learn to integrate CS principles across K-12 curricula: an annual week-long *Summer Institute*, and *follow-up support* through undergraduates enrolled in the college field experience course. Our week-long *Summer Institute* focuses on preparing teachers in grades 5-12 to integrate CS principles into existing STEM modules. It includes explicit attention to CS content, pedagogical knowledge for teaching CS using a variety of CS resources and tools, and strategies for broadening participation in computing (Authors, 2015; see Table 1 for an overview).

Table 1

Overview of *Summer Institute* PD Schedule (2019)

<table>
<tr><th>Time</th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th></tr>
<tr><td>9:00-10:15</td><td>Introductions, Program Purpose & CS Unplugged – Icebreaker</td><td>Explore Algorithm Lesson Plans & CS Unplugged – Algorithms</td><td>Assessing Scratch Products for Creativity, Rubrics & Dr. Scratch</td><td>Creating a VR scene using A-Frame</td><td rowspan="2">Finalize Lesson Plans & CS Unplugged – Abstraction</td></tr>
<tr><td>10:15-10:30</td><td colspan="4">Break</td></tr>
<tr><td>10:30-11:45</td><td>Programming with Ozobots using Two Languages (Color Lines & Block-Based)</td><td>Continuation of Algorithms Lesson & Culturally Responsive</td><td>Data Abstraction with CORGIS Visualizer</td><td>Creativity with Micro:bits</td><td>Lesson Sharing & Broadening Participation</td></tr>
<tr><td>11:45-12:30</td><td colspan="4">Lunch</td><td rowspan="6">Adjourn</td></tr>
<tr><td>12:30-1:00</td><td>Broadening Participation in Computing</td><td rowspan="2">CS First with Google Representative</td><td>CS Unplugged – Live Guess Who Game & Explore Lessons on Querying</td><td>CS Unplugged – Internet & Cybersecurity</td></tr>
<tr><td>1:00-2:15</td><td>Continuation of Ozobots – Introduce Creativity and Brainstorm Lessons</td><td>Digital Art in Pixels</td><td>CS Toys: Exploring Computational Curriculum Kits</td></tr>
<tr><td>2:15-2:30</td><td colspan="4">Break</td></tr>
<tr><td>2:30-3:45</td><td>From Standards to Lessons & Culturally Responsive</td><td>Continuation of CS First with Google Representative</td><td>Culturally Responsive Lesson Planning, Lesson Development & Peer Feedback</td><td>Culturally Responsive Lesson Planning, Lesson Development & Peer Feedback</td></tr>
<tr><td>3:45-4:00</td><td colspan="4">Reflection on Learning</td></tr>
<tr><td>4:00-4:30</td><td colspan="4">Adjourn & Individual Consultations</td></tr>
</table>

In this work, *content* refers to big ideas of CS, including creativity, abstraction, data, algorithms, programming, Internet, and impacts of computing (College Board, 2017). *Pedagogical knowledge* refers to knowledge of general pedagogical strategies, such as inquiry and collaboration, as well as knowledge specific to the teaching of CS, including: (a) pair-programming - a technique where two programmers work together at the same station; (b) CS unplugged - kinesthetic activities that teach CS concepts without computers (Bell et al., 2008); and (c) process oriented guided inquiry learning (POGIL) – activities that engage students in active construction of learning while working in small teams (see https://pogil.org). Specifically, teachers acquire pedagogical knowledge by participating in pair programming, open-ended projects allowing for creativity, a variety of CS unplugged activities, collaborative projects, assessment of computational artifacts, and sustained reflection (*active learning*). Additionally,

participants engage in activities that help them draw connections between key ideas in computing and core curricular standards by working in teams to design CS-integrated lessons (*coherence & collaboration*). PD instructors as well as other peers provide feedback to lesson drafts. Finally, a series of sessions focus on the impacts of CS on society and promising practices for recruiting and retaining diversity in CS.

While our *Summer Institute* provides opportunities for the development of CS knowledge and pedagogy, teachers need ongoing support throughout the academic year (*sustained duration*). To accomplish this goal, we established a *Field Experience* university service-learning course. The field experience course is open to undergraduates with at least one prior course in CS. It combines college classroom meetings with field-experience in schools. During the College meetings, undergraduates and faculty in CS and education work together to: (a) identify computing lessons and activities relevant to students' age group, interests, and prior experiences; (b) model pedagogical strategies for teaching CS that have shown promise in broadening participation in computing; (c) prepare and analyze computing lesson plans; and (d) reflect on successes and challenges during the field experience (Authors, 2016). In the field, undergraduates meet with teachers to discuss lesson plans, solicit input, and work out logistics. They also co-facilitate classroom activities or after-school programs with their partner teacher (Authors, 2016).

Culturally Responsive & Equity-Focused PD Model

Our PD program has expanded to include a culturally responsive and equity-focused framework aimed at engaging teachers and undergraduate student facilitators in *self-reflection* and culturally responsive teaching strategies (Authors, 2019; 2020). We began to pilot our culturally responsive PD model during the 2018 *Summer Institute*. This first iteration focused on highlighting the underrepresentation of racially minoritized and female students in CS and preparing teachers with techniques for attracting, maintaining and engaging students from these underrepresented groups. Teachers participated in two PD sessions aimed at broadening participation in computing, during which facilitators dispelled myths about underrepresented groups in CS (e.g., girls are not interested in computing) and addressed the impact of personal biases and microaggressions in CS (Gershenson et al., 2016). These sessions engaged teachers in self-reflection to examine their own biases, specifically biases pertaining to perceived intellectual abilities based on race, gender, and socioeconomic status (Howard, 2003). Teachers also participated in four PD sessions focused on integrating CRP into their lesson planning, during which facilitators introduced CRP and examples of CRP in CS (Gay, 2018; Ladson-Billings, 1995b; Nieto, 1999; Scott et al., 2010). These sessions focused on preparing teachers to integrate knowledge relevant to youth identities and communities with computational learning activities.

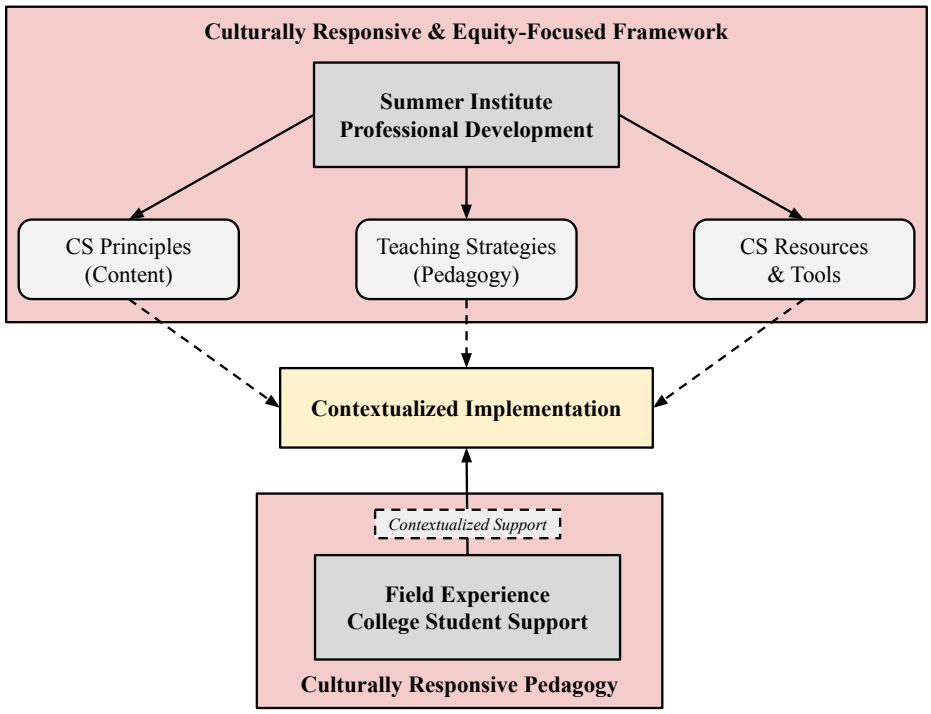
In the pilot version of our culturally responsive and equity-focused framework, we sought to offer teachers insight into underrepresentation in CS and noted the importance of self-reflection in becoming a culturally responsive teacher. Following the 2018 *Summer Institute*, we conducted a series of semi-structured interviews to evaluate the effectiveness of this framework (Authors, 2019). Findings suggested that facilitators were able to successfully communicate the need for equity and culturally responsiveness in CS education. The PD sessions motivated teachers to incorporate CRP and equity-focused practices in their lessons. However, teachers left the PD with an inconsistent understanding of CRP and many teachers reported feeling unsure of how to implement CRP in their own classrooms. As one teacher explained, CRP prioritizes "recognizing my own biases that I would have internally, which I'm not aware of, so I'm not

sure how I'm going to do that" (Authors, 2019). Our initial approach to CRP PD lacked the specificity teachers needed to successfully confront personal biases, implement pedagogical changes, and adapt their CS curriculum. In response to these findings, we adapted our PD model to integrate our culturally responsive and equity-focused framework into every aspect of our program (Figure 1), including all three elements of the *Summer Institute* and the contextualized support provided by our undergraduate student facilitators.

Our revised PD model focuses on preparing teachers to successfully implement CRP in their CS classrooms (Figure 1). Beginning in the fall of 2018, we also integrated our CRP focused-sessions into the curriculum for undergraduate student facilitators. These sessions prepared undergraduate facilitators for culturally responsive teaching by engaging them in self-reflection and equipping them with culturally responsive teaching strategies. Expanding our framework to include undergraduate facilitators provided teachers with contextualized and individually tailored support as they sought to integrate CRP into their own CS classrooms. Our revised PD model seeks to better prepare teachers for successfully implementing CRP by expanding the framework to encompass all three indented outcomes of our *Summer Institute* (Figure 1). In addition to engaging teachers in self-reflection and promoting specific CRP teaching strategies (pedagogy), the revised model provides teachers with culturally responsive resources and contextualized approaches for integrating CS principles (content). To incorporate CRP into the CS principles, we emphasized creativity as a central principle for creating culturally responsive curriculum and assessments.

Figure 1

Culturally Responsive and Equity-Focused PD Model (Authors, 2020)



During the 2019 *Summer Institute,* we focused on four specific CRP elements: promoting diversity, self-reflection, centering equity, and implementation (Table 2). Sessions promoting

these elements appear on our schedule under two designations: *broadening participation in computing* and *culturally responsive* (see Table 1). Each session lasted approximately 30 minutes. To promote diversity, teachers learned research-based strategies for increasing participation in CS and make their curriculum relevant through addressing real-world problems. Teachers engaged in self-reflection to confront biases, practice addressing microaggressions, and apply a cultural lens. To center equity, teachers engaged in sample activities and learned to center creativity in their lesson design. To promote implementation, teachers worked collaboratively to integrate CRP concepts while writing conceptual lesson plans. These four CRP elements were chosen to deepen teachers' understanding of CRP and prepare them to successfully incorporate CRP and equity-focused practices in their classrooms.

Table 2

Culturally Responsive and Equity-Focused PD Elements

Element	Purpose/Explanation	PD Activities	Literature
Promoting Diversity	Increasing participation in CS through equity-focused and research-based approaches Making CS relevant to solving real-world problems	"Identify, Recognize, Invite, Invite Together"	Alvarado, Dodds, & Libeskind-Hadas, 2012
Self-Reflection	Defining CRP and reflecting on the impact of culture Thinking about ourselves and our students through a cultural lens Dispelling myths and confronting internal biases Identifying and avoiding microaggressions	Partner Walk Five Minute Poems Identity Wheel Identifying & Dispelling Myths Addressing Microaggression	Gay, 2018; Gershenson, Holt, & Papageorge, 2016; Ladson-Billings, 1995b; Nieto, 1999; Tatum, 2007
Centering Equity	Adapting pedagogical approaches Centering culturally responsive interactions	Examples of CRP in CS Designing Robots to Save the World Exploring Shared Interests Assessing Creativity	Pollock, 2008; Scott, Clark, Sheridan, Mruczek, & Hayes, 2010
Implementation	Integrating CRP concepts into CS lesson plans Adapting existing curriculum to be culturally responsive	Peer feedback and support; individual and contextualized support	

During the PD, we addressed each of the four CRP elements through a series of activities adapted and implemented by the PD facilitators. Table 3 provides detailed descriptions of six key activities from our 2019 *Summer Institute*. Each activity was selected to promote engagement with the CRP elements and adapted to meet the needs of our participating teachers. This paper focuses on how teachers processed and applied CRP and equity during the 2019 *Summer Institute* and subsequently *in their classrooms* during the 2019-2020 school year.

Table 3

Description of CRP-related PD Activities

PD Activity	Description
Identify, Recognize, Invite, Invite Together	After helping teachers dispel common myths about why there are fewer female and BIPOC students in CS classes, they learned a four-step approach for improving the recruitment and retention of these minoritized students based on the successful recruitment and retention of female students in CS at Harvey Mudd College (Alvarado, et al., 2012). Teachers learn to identify promising students, recognize them for their abilities and achievements, invite them to take a CS class (or a more advanced CS class), and invite groups of students to sign up for CS classes together.

Partner Walk	Teachers engaged in self-reflection by telling personal stories. Pairs of teachers take a walk during which they take turns talking for three minutes straight about unique traditions from their family or culture. This activity was developed by Liz Brown at the University of Canterbury, who based this work in the Māori tradition of whānau or *extended family*.
Five Minute Poems	This activity was developed by Beverly Tatum (2007) to engage teachers in a written reflection on the community and culture that contextualized their childhood. The poem consists of four stanzas that each begin with the phrase "I am from." The first stanza contains the familiar sights, sounds, or smells from their neighborhood. The second stanza describes familiar foods they grew up eating. The third stanza shares family sayings and the fourth stanza describes specific people who influenced their life.
Social Identity Wheel	Teachers reflect on some of their social identities (race, gender, sex, (dis)ability, sexual orientation, etc.) and reflect on how these identities impact their self-perception or how they are perceived by others. For this activity, teachers complete the social identity wheel worksheet adapted for use by the Program on Intergroup Relations and the Spectrum Center, University of Michigan.
Addressing Microaggressions	Teachers were given examples of microaggressions female and BIPOC students may face in CS classrooms. Teachers worked in groups to practice identifying and addressing each scenario. This activity was adapted from the Computer Science Teaching Tips website (csteachingtips.org).
Designing Robots to Save the World	This activity asks teams of teachers to design a robot that would make the world a better place. The development of this world-changing robot relies on a combination of creativity, problem solving, and technological design as they work together to address real-world problems. This activity was originally designed by our team for middle school students in an after-school coding program.

Methods

Participants

For this study, we focus on teachers who participated in our program during the 2019 *Summer Institute.* Specifically, a total of 25 teachers attended the 2019 Summer Institute. Of those, we used criterion sampling to recruit participants who worked in schools that serve a racially and socioeconomically diverse population (n=9). All nine selected teachers designed conceptual lesson plans (i.e., lesson plans that teachers planned to apply in their classrooms) and participated in individual interviews on the last day of the 2019 *Summer Institute*. Of these, six teachers completed an online questionnaire and provided an applied lesson plan (i.e., lesson plan that teachers implemented in their classroom) following their participation in the Summer Institute. Further, four of these teachers previously attended our 2018 *Summer Institute* and participated in the pilot version of our culturally responsive and equity-focused PD model. In addition to core elementary teachers, participants taught business, technology, and library classes at either the elementary or middle school level. Several participants also taught after school CS programs. Table 3 provides an overview of the participants and associated data.

Table 3

Participant Demographics

Pseudonym	Race	Gender	Experience	Grade Level
Beth†	White	F	9 years	Elementary
Cindy *†	Asian	F	12 years	Elementary
Deborah *†	Black	F	7 years	Middle School
Emma†	White	F	6 years	Elementary
Kathy *†	White	F	23 years	Middle School
Lane	White	F	26 years	Elementary

Mary *†	White	F	22 years	Middle School
Sandy	White	F	8 years	Elementary
Tara	Black	F	11 years	Elementary

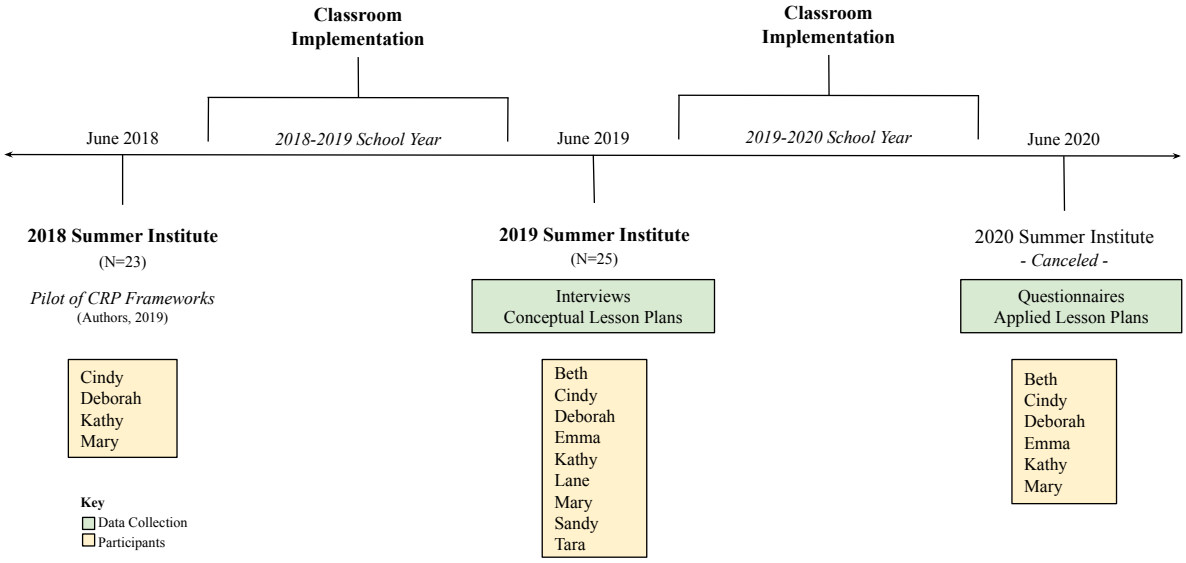
Notes. All participants completed individual interviews on the last day of the 2019 *Summer Institute*.
* Participated in 2018 Summer PD
† Completed 2020 Online Questionnaire and Submitted 2019-2020 Applied Lesson Plans

Data Collection

Qualitative data were collected from four sources: individual interviews and conceptual lesson plans collected during the 2019 *Summer Institute*, an online questionnaire and applied lesson plans collected following the 2019-2020 school year (Figure 2).

Figure 2

Timeline of PD Activities and Data Collection



Interviews

On the final day of the 2019 *Summer Institute*, we conducted semi-structured individual interviews with participating teachers (n=9). Teachers were asked nine questions that targeted their experiences during the PD, the effectiveness of the culturally responsive sessions, and potential needs for follow-up support. Four questions were specific to the CRP elements of our PD, which asked teachers to: (1) define CRP, (2) identify connection between CRP and CS, (3) provide an example of how students can use technology to solve real-world problems in their community, and (4) explain how they plan to apply what they learned about CRP following the PD. The four teachers who attended the previous year's PD offerings (see Table 3) answered three additional questions: (1) reason for attending multiple years, (2) applications of CRP in their classroom following the previous year's PD, and (3) the perceived impact of the second year of PD on their knowledge of CRP. Interview data were de-identified prior to analysis to avoid analysis bias.

Conceptual Lesson Plans

Participating teachers worked independently (n=4) and in small groups of 2-4 throughout the week-long *Summer Institute* to design a conceptual lesson plan – a CS lesson plan that could be used in their own classrooms. On the final day of the PD, we collected conceptual lesson plans (n=9) from all participants. In addition to a detailed lesson plan, teachers were asked to indicate the target audience (grade level and subject area), lesson goals, CS standards, required technologies, and learning assessment. Teachers were also asked to detail how they sought to apply CRP in their lesson plan. Teachers designed lesson plans that could be used for multiple content areas in addition to CS classes, including language arts, math, business, and library. Lesson plans covered a wide range of CS topics ranging from programming robots to programming fairytale story boards all the way to HTML lessons. Digital copies of each lesson plan and accompanying materials were collected via Google Drive. Additionally, teachers created posters depicting key elements of their lesson plans, which were presented on the final day. We refer to these lesson plans as "conceptual" because they provide data about how teachers *planned* to implement CRP into their teaching.

Questionnaire & Applied Lesson Plans

In spring 2020, due to COVID-19, we administered an online questionnaire via Qualtrics (instead of in-person interviews) that consisted of seven questions, which asked teachers to self-report their use of CRP elements during the 2019-2020 school year. Teachers were asked to (a) describe what they think it means to be a culturally responsive CS teacher; (b) give two examples of how they have implemented CRP; (c) identify what support they need to maximize their success in implementing CRP; and (d) self-report how often they incorporated four specific tenets of CRP in their CS classroom: paired programming, creativity, student-led activities, and real-world problem solving. Following the questionnaire, teachers were asked to submit one culturally responsive lesson plan they had taught during the 2019-2020 school year. Lesson plan format and content varied by teacher. We refer to these lesson plans as "applied" because they provide data about how teachers *applied* CRP in their classrooms after attending the PD.

Data Analysis

Interview (de-identified) and questionnaire data were analyzed to identify common and unique themes, using an analytical approach inspired by grounded theory (Glaser & Strauss, 1967). Data were coded based on emergent themes and categories, which were applied during two rounds of coding. Themes were categorized for analysis based on our first research question, which examines how teachers are conceptualizing CRP and equity in the context of CS. Interview and questionnaire data were analyzed based on four emergent themes: (a) cultural awareness, (b) student-centered pedagogies, (c) inclusion and belonging, and (d) equal access.

Lesson plan data were analyzed to examine how teachers applied CRP to their pedagogical and curricular design. For this analysis, we developed a codebook, which drew from three lesson assessment rubrics (Aguilar-Valdez, 2015; Utah Valley University, n.d.; Weintrop et al., 2019). Codes were grouped into two code categories (equity & inclusion and content & pedagogy) and refined during two rounds of coding by the researchers. Lesson plan data were analyzed in a third round of coding using our final codebook (Table 4).

Table 4
Codebook for Lesson Plan Analysis

Equity & Inclusion	
Code	*Criteria*
Culture	Incorporates the diverse cultures, perspectives, languages, and community values of students (cultural heritage and contemporary youth culture) Gives students the opportunity to share their own culture and cultural heritage Lesson incorporates real-life connections Connects learning to students' homes, neighborhoods, and communities
Authentic Identity	Connects to students' interests without relying on stereotypes Opportunities for students to contribute their knowledge, perspectives, and experiences related to lesson topic Student identities represented in the curriculum and classroom materials Opportunities for students to represent themselves in their projects
CS Identity	Creating a space that encourages a sense computer scientist identity
Exceptionalities	Adapted for a variety of different types of learners (*e.g. ELL, Special Ed*) using alternatives, such as translations, pictures, and graphic organizers Extensions activities for students who meet the performance expectations Assessment methods are accessible and do not penalize for exceptionalities
Social Justice	Connect learning to social, political, or environmental issues
Content & Pedagogy	
CS Content	Coverage of the non-CS topics used as framing (*e.g. historical events*) Aligns with standards (*e.g. K-12 CSTA Computer Science Standards*) Content follows trajectory from less to more complex Integrates disciplinary terminology and promotes student usage Content tailored to student prior knowledge and skills within CS
Pedagogical Practices	Students engage in computing skills and computational thinking Collaboration or peer-feedback Engaging and varied instructional approaches and learning strategies (*e.g. discussions and student-centered approaches*) Opportunities to share completed work with classmates and/or community
Instructional Design	Incorporates prior knowledge unrelated to CS content (*e.g. cooking, music*) Questions promote higher order thinking (*apply, analyze, evaluate*) Scaffolding to promote understanding and independence (*Use-Modify-Create*) Opportunities to explore and provide solutions to open-ended questions Provides opportunities for students to reflect and express their learning
Assessment	Objective-based assessments present throughout instruction Clear assessment criteria shared with students Students involved in self-assessment

Results

Findings revealed that, following participation in the culturally responsive and equity-focused *Summer Institute*, teachers were able to understand and apply CRP to support CS instruction in the context of their individual classrooms.

Conceptual Understanding

Participating in the *Summer Institute* helped teachers form a clear conceptual understanding of CRP in the context of CS education.

Conceptualizing & Contextualizing CRP in CS

The revisions to our culturally responsive framework and PD model helped teachers develop a more robust understanding of CRP. Findings from our initial pilot study revealed that our teachers initially developed a shallow and inconsistent understanding of CRP following our 2018 *Summer Institute* (Authors, 2019). In contrast, at the end of their participation in our 2019 *Summer Institute*, teachers articulated their understanding of CRP through cultural awareness, student-centered pedagogies, inclusion and belonging, and ensuring equal access.

Cultural Awareness. In discussing the importance of cultural awareness, teachers identified three underlying elements: centering cultural differences, adapting classroom culture, and engaging in thoughtful reflection. First, teachers demonstrated a willingness to center students' cultural needs and differences in designing their learning environment. Emma explained that being culturally responsive is "making sure that your teaching practices and your classroom environment" meet the "cultural needs of your students." Several teachers also noted that knowing your students and accommodating cultural needs can improve student experiences in CS. Second, teachers recognized the need to adapt classroom culture to be more responsive to their students. As Sandy explained, "Sometimes during the day . . . something might happen with our kids and that might not be the time for us to discuss it, but them knowing . . . that I can come to my teacher and we can talk." For this teacher, creating space to adapt to student needs is an important aspect of being culturally responsive. Adapting classroom culture contributes to creating an inclusive classroom environment, which is the foundation of being culturally responsive. Third, teachers acknowledged the role of thoughtful reflection in their development as culturally responsive educators. Addressing authentic equity issues contextualized in educational settings helped teachers recognize the importance of acknowledging different points of privilege and taking a step back to say, "Oh, wait a minute. This isn't the starting point for most of our students" (Cindy). After "pushing past those barriers and biases," we can truly grant "access to everybody" (Beth). Through cultural awareness, teachers were able to theorize how they could apply a cultural lens in their own classrooms.

Student-Centered Learning. Teachers also understood CRP as a way to center their learning environments around student needs, cultural identities, and student-centered pedagogy. At the end of their participation in the *Summer Institute*, teachers acknowledged that CS education is not about "students just fitting in one mold," because such an approach means "completely neglecting an entire population of people because we're not looking at their needs" (Cindy). Teachers recognized that part of CRP is acknowledging and valuing students' unique learning needs, backgrounds, and interests. Additionally, teachers mentioned adopting a student-centered pedagogy to meet their students' needs by adapting their teaching style or learning environment. As Cindy explained, "A lot of students really do love computers and if we encourage those students to be more involved with computer science, maybe we're going to bring out a strength that we didn't know they had" because "this is the way teaching should be. Kids need to touch and build and make." Through student-centered pedagogies, teachers were able to reimagine their classrooms as culturally responsive spaces that could meet the needs of their own unique students.

Inclusion & Belonging. Teachers discussed ways to create a sense of inclusion and belonging through emphasizing membership and student identity in CS classrooms. Teachers described CRP as a way to unite and bring students together as a community. Cindy described CS as a meaningful way to "pull in kids that don't feel like they are contributing members of our community," especially students who feel like they are "not good here." Rather than labeling students based on language abilities or behavior needs, "computer science is a way to unify everybody and say hey, we're all learning something new. Nobody knows how to do this" (Cindy). Kathy described CRP as a way to "make sure all students feel like they could be successful in computer science." She sought to promote belonging by identifying groups using pictures of CEO's, including several women and people of color. She wanted her students to see themselves represented beyond the stereotypical "white male" CEOs. Teachers also thought about CRP as a way for students to come into their identities and personalities. According to Cindy, being culturally aware is "about being open to every possibility that could exist and not be closed off" and not limiting students to a group "because people identify in different ways and they change." As Cindy put it, "it's a mindset for the educator to be adaptable and to be open." In a diverse school environment, it is important to "make sure they all know that everybody can be successful in computer science" (Kathy). Through inclusion and belonging, teachers began to center student identity and apply CRP to promote an inclusive classroom environment.

Equal Access. Teachers identified the need to make culturally responsive pedagogical changes that would prioritize equal access. For example, teachers suggested utilizing CS Unplugged activities to promote CS exposure, even when access to technology was limited. Teachers also recognized that students may have a lack of resources inside and outside of the school to do CS activities using computers. According to Tara, the essence of CRP in CS is that, everyone "should have access to what we're doing, somehow at some level." Following the PD, teachers recognized the importance of CS for all students. Several teachers discussed ideas for recruiting and retaining racially minoritized and female students into computing clubs to give them access and exposure to CS. Teachers thought about CRP as a model for creating equal access that would help diversify CS.

Integrating CRP into Conceptual Lesson Plans

Conceptual lesson plans developed during teachers' participation in PD, provide insight into how teachers planned to integrate elements of CRP when selecting content and pedagogical approaches in order to promote equity and inclusion. Findings are divided into two categories: (1) equity and inclusion, which examines how teachers plan to address issues of culture, identity, exceptionalities, and social justice within their lesson; and (2) content and pedagogy, which examines how teachers plan to adapt their content and pedagogical approaches to be culturally responsive.

Equity & Inclusion. Teachers successfully incorporated elements of equity and inclusion into their conceptual lesson plans. Three conceptual lesson plans incorporated connections to diverse cultures. In one lesson plan, fairytales from different heritages were collected to explore and recognize students' identities. Seven conceptual lesson plans included expressions of authentic identity within CS activities. For example, Deborah planned to have her students develop a program based on an adaptation of the Five Minute Poem activity (Tatem, 2007), which she expected to help her learn about her students' authentic identities. One conceptual lesson plan promoted CS identity to increase students' sense of belonging in the field of CS. For example, students cultivated their digital identities and teachers designed activities to promote

digital citizenship. Six conceptual lesson plans indicated adaptations for accommodating student exceptionalities. For example, teachers planned to provide material in different languages for English language learners to ensure learning is accessible for all students. Teachers did not plan to address issues of social justice with students in their conceptual lesson plans.

In one conceptual lesson plan, a group of upper elementary teachers proposed a lesson on fairy tales that integrated CS into their ELA curriculum. This lesson satisfied three of the equity and inclusion subcategories: culture, authentic identities, and exceptionalities. The lesson began with students watching a video that detailed the story of Little Red Riding Hood. To accommodate for exceptionalities, teachers also provided a transcript of the video. After viewing the video, students were encouraged to use a variety of resources (e.g. libraries, family members, and search engines) to research a new fairytale that they could rewrite to reflect their own heritage or identity. The lesson plan included a graphic organizer to help students compare and contrast elements of an original fairy tale to their own traditions. Finally, students were to create an AR/VR fairytale on CoSpaces and share their creations during a gallery walk activity. A detailed rubric was also included to provide students with a clear indication of expectations. This conceptual lesson plan incorporates the diversity of their students without relying on stereotypes and gives students the opportunity to represent themselves creatively in their projects. These teachers considered the various learning exceptionalities students may have and listed alternative accommodations to overcome barriers and ensure equal access. Finally, assessment expectations were accessible to all students and did not penalize for exceptionalities. The activities in this lesson were created for a classroom environment with access to technology and the Internet.

Content & Pedagogy. Teachers successfully incorporated CRP into the content and pedagogy of their conceptual lesson plans. All nine conceptual lesson plans incorporated CRP into their CS content to promote student engagement. For example, teachers designed lesson plans around CS standards and tailored content to students' anticipated knowledge and skills. All nine conceptual lesson plans indicated culturally responsive pedagogical practices. To this end, teachers planned to use strategies such as paired programming to promote collaboration and accommodate exceptionalities. Seven conceptual lesson plans included responsive instructional design to scaffold new content and promote independent learning. For example, teachers included time for modeling, student exploration, and answering questions throughout their lessons. Five conceptual lesson plans included plans for clear, unbiased assessment. Teachers included informal assessments to ensure student success and provided detailed rubrics that would allow students to self-assess prior to submitting their final product.

In one conceptual lesson plan, a group of middle school teachers planned to use game development to introduce middle school students to step-by-step algorithmic processes to write code. This lesson satisfied all four of the content and pedagogy subcategories: CS content, pedagogical practices, instructional design, and assessment. Teachers began their lesson plan with a CS Unplugged activity to support computational thinking using dice. This activity encouraged "students to think about specific steps it takes to play, which provides the foundation for programming" and ultimately transition into skills for block coding in Scratch. Learning strategies such as a pair programming were included in the lesson to support student collaboration. Together, students were assigned to watch a how-to video on creating a "Racing Game" project in Scratch on CS First. Teachers used the appropriate disciplinary terminology throughout the lesson and encouraged students to do so through a guided discussion and reflection questions. To promote further collaboration and peer feedback, pairs that completed their work could partner up with other groups to share their finished products. The lesson

concluded with a whole class discussion and exit ticket that provided students with the opportunity to reflect on what they had learned. Finally, a rubric was included in the lesson plan for students to use for self-assessing their projects. Overall, this lesson plan tailored appropriate CS content to students' knowledge and skill levels, provided the opportunity for collaboration, and included relevant assessment practices. This lesson plan included equitable practices such as incorporating real life connections and extension activities that challenged students who met expectations.

Applied Understanding

After participating in the *Summer Institute*, teachers successfully incorporated CRP into their own classrooms through learning environment design, pedagogical approaches, and adapting course content.

Applying CRP in CS Classrooms

Findings revealed that teachers were able to maintain and contextualize their understanding of CRP following the PD. Specifically, teachers continued to conceptualize CRP in terms of cultural awareness, student-centered pedagogies, and equal access. In their discussions of cultural awareness, teachers held themselves responsible for understanding and adapting to cultural diversity in their classrooms. In addition to cultural awareness, Kathy stated that teachers must also understand "there are underserved populations in computer science due to bias." Mary also emphasized that teachers must translate their awareness into action: "Then, once the information is known, insisting on doing the best job to take the information into account and modifying behavior." Teachers also emphasized the importance of student-centered pedagogies for culturally responsive teaching. According to Tara, "students' involvement in the application of counter science to their lives is key." She went on to explain that, in her experience, "Many students respond to teaching that demonstrated computer science changing people's lives, such as wearable technology that helps someone with a disability complete the task." Finally, teachers noted the importance of CRP in promoting equal access. As Beth wrote, "Being a culturally responsive computer science teacher is making it important that all students in our schools have access to computer science opportunities." To this end, she created a CS club "where teachers encouraged students of all genders and ethnicities to join" (Beth). Throughout their responses, teachers emphasized the importance of *action* in being a culturally responsive educator.

Teachers reported using specific tenets of CRP in roughly half of the lessons they taught. Creativity was the most used tenet, as four teachers reported using creativity "most of the time" and one teacher (Mary) reported "always" using creativity in her lesson planning. According to Tara, "There are so many opportunities for students to put their creativity to use, and there's more potential across all areas of the economy than many people realize." Real-world problem solving was the least utilized tenet, as two teachers reported "sometimes" using real-world problems and one teacher (Cindy) reported "never" using real-world problems in her lessons. When asked to provide examples of how they have implemented CRP, five teachers provided examples of how their lessons built on student interest and knowledge. Emma reported creating activities that "engage the students based on suggestions of topics they would like to cover." Three teachers reported designing activities that provided students choice to incorporate their

own interests. To support their use of CRP, teachers stated their need for additional culturally responsive and grade-specific examples and resources.

Integrating CRP into Applied Lesson Plans

Applied lesson plans provide insight into how teachers applied CRP in their classrooms after participating in our *Summer Institute* (2019-2020 academic year). Specifically, we examined how teachers applied CRP when selecting content and pedagogical approaches in order to promote equity and inclusion in their own classrooms. Findings are divided into two categories: (1) *equity and inclusion*, which examines how teachers applied CRP to address issues of culture, identity, exceptionalities, and social justice within their lesson; and (2) *content and pedagogy*, which examines how teachers applied CRP in adapting their content and pedagogical approaches within their own classrooms.

Equity & Inclusion. Teachers successfully incorporated elements of equity and inclusion into their applied lesson plans. Five applied lesson plans incorporated cultural approaches in their design. For example, Beth encouraged students to program a gaming story specific to who they are. Three applied lesson plans included aspects of authentic identity. For example, Kathy encouraged students to work together to compare and contrast their cultures and create a visual display for the class. Three applied lesson plans promoted CS identity to promote a sense of belonging in the field of CS. For example, Deborah had her students decorate the classroom door with information about what CS looks like in the real world and why it is important. Three applied lesson plans included accommodations for student exceptionalities. For example, Kathy used accessible websites that allowed for text adjustment and read aloud features for students. One applied lesson plan (Kathy) included a social justice dimension to teach CS. In this lesson plan, students explored the relationship between culture and climate change.

In her applied lesson plan, Kathy centered around world cultures and languages in an engaging lesson for her middle school students. First, she directed students to research culture and what it looks like around the world using reliable online sources. In this way, Kathy was able to incorporate diversity and make real-life connections. After the non-CS introductory activity, she led a whole class discussion about culture and how various identities were represented in their classroom. Each student had the opportunity to contribute, drawing on their own knowledge, perspectives, and experiences. Using pair programming, students then coded projects in Scratch that incorporated their individual culture and heritage. Unique to this lesson plan, Kathy dedicated time to discuss collaborative group norms with her students. She also considered student's learning exceptionalities, choosing content that included pictures, videos, and audio clips. Kathy created an impactful learning experience, which allowed students to represent themselves authentically in their learning and collaborate with their peers.

Content & Pedagogy. Teachers successfully incorporated CRP into the content and pedagogy of their applied lesson plans. Six applied lesson plans incorporated CRP into their CS content. For example, Emma incorporated appropriate CS terminology in her instruction and students were encouraged to apply the terminology in their write up. Six applied lesson plans indicated the use of culturally responsive pedagogical practices. As in their conceptual lesson plans, many teachers relied on paired programming to promote collaboration. Five applied lesson plans included culturally responsive instructional design to promote student learning and reflection. For example, Beth and Cindy ended their co-taught lesson with a wrap up discussion, in which students reflected on what they learned and their role as computer scientists. Five applied lesson plans included plans for equitable student assessment. Teachers included

objective-based assessments, such as an exit ticket in which students drew their maze and wrote out the code they used to guide a mouse through it.

In her applied lesson, Deborah engaged middle school students in CS through creative expression and contemporary youth culture. Her lesson began with a unique warm-up activity to encourage the formation of CS identities. Using her classroom door, Deborah encouraged students to fill the space with their ideas about what CS means and why it matters to them. Next came the dancing. Students danced in their own individual and creative ways to a playlist with music from a variety of different languages and genres. Deborah designed this lesson to "combine coding with dancing in a creative way." Next, students recorded themselves and watched a playback of their dance moves. Finally, students coded a dance party in Scratch following the sequence of their dance moves. They were able to represent their individuality through their choice of dance moves and music. In her lesson plan, Deborah explained, "Learners of all ages get an introductory experience with coding and computer science in a safe, supportive environment." She also planned for how to address potential barriers depending on the dynamics of the classroom, such as the ability to read and having access to sound as the whole activity was built to respond to music.

Discussion & Conclusion

CS education research indicates teachers frequently hold deficit-oriented views about the fit between CS and students of color (Margolis et al., 2017). PD programs that help teachers learn about inequities in CS and how to incorporate CRP to make computing more inclusive are needed (Goode, Ivey et al., 2020). This paper presented the outcomes and impact of our week-long *Summer Institute* on teachers' use of CRP in CS instruction. Findings of this study were supplied by a series of interviews from teachers after completing the *Summer Institute* and lesson plans teachers constructed during that time. Statements teachers made in interviews and examples of CRP in lesson plans indicate that teachers developed a strong foundational understanding of what it means to be culturally responsive and equity-focused. By offering teachers resources, training, and skill development during their participation in PD, we were able to effectively influence the way teachers will construct or use culturally appropriate content, pedagogy, and CS tools. Previous models at the *Summer Institute* left teachers with a basic understanding of CRP and thirst for contextualized support. Thus, although sessions were short yet intensive, the current PD model was able to successfully establish the importance of CRP and articulate the need for equity-based learning environments for diversity in CS.

Attending our *Summer Institute* helped teachers develop a strong foundational knowledge of what it means to be a culturally responsive educator and ways to create an equity-focused learning environment. For teachers with repeated attendance, our PD established a lasting and influential impact on the way they use culturally appropriate instructional practices in their classrooms. This finding is important because literature shows that shifts in such teaching practices can support an equitable learning environment, provide encouragement and meaningful learning experiences to underserved students, and improve students' academic achievement (Bishop et al., 2009; Goode, Ivey et al., 2020; Prater, 2014).

Future research needs to follow teachers into their classrooms to understand and observe changes in instructional implementation and the implementation of CRP specifically (Mellom et al., 2018). Additional PD opportunities and CRP resources should be constructed around contextualized support for communication strategies, assessment practices, and challenges with

student expression. Importantly, research should continue to build on best practices for teacher PD that respond to contextualized approaches and application of CRP.

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