Culturally Responsive Computing in Teacher Training: Designing Towards the Transformative Learning of Girls in STEM

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Abstract

This paper reports on the findings of a Design-Based Research (DBR) study that investigated the transformative learning of six high school computer science teachers after they participated in a professional development (PD) training with a focus on Culturally Responsive Computing (CRC). Findings from the statistical analysis of pre-and post-surveys reveal ways in which teachers' understanding and enactment of CRC in their classrooms led to a reporting of increased student engagement, a deeper understanding of diverse learning needs, and improved access to cultural resources to specifically meet girls' needs. Findings from interviews and focus groups further reveal that after engaging in the PD, teachers qualitatively adapted their classroom strategies in order to uplift the cultural practices and gender identities of historically marginalized students. This study has implications for how teachers' professional development is designed and how they are guided to enact culturally responsive computing in ways that help recruit and retain racial and ethnic minority girls in CS courses.

Keywords: Culturally Responsive Computing, Teachers' Professional Development, Girls' participation in computer science, Intersectionality, Transformative learning

1. Introduction

The main goal of this research is to understand the impact of professional development in subject-specific Computer Science (CS) content using culturally responsive computing (CRC) on teachers' instruction of rigorous CS coursework and their ability to support students and underrepresented girls in the ICT pathways. The intervention described in this article is a concerted attempt at addressing a pipeline issue regarding the lack of diverse representation in CS, namely the enrollment of girls in this disciplinary domain ((NCES, 2020). From August 2019-September 2021, we conducted a Design Based research (DBR) that consisted of mixed methods study. In order to develop a High School and Researcher-Practitioner Partnership (RPP), which is a crucial tool to sustain equity research (Vetter et al., 2022), faculty professors from the teaching credentials and computer science departments at a Northern California University, partnered with computer sciences teachers from a very diverse Northern California school district, which consists of various races and underrepresented minorities.

All computer science courses in this district are taught in six high schools' "Information and Communication Technology" (ICT) career pathways; career pathways are a rapidly growing reform movement in California, especially in high needs districts that enroll large numbers of low-income, diverse students. During the 2017-2018 academic year, forty-eight percent of the total high school population at these six schools were girls. During the 2017-2018 academic year, 155 girls participated in the six ICT pathways. This means that only 25% of students enrolled in ICT are girls. The rationale is to leverage girls and underrepresented students' shared interests in ICT, by infusing Culturally Responsive Computing in the content so that it becomes more engaging, appealing, and inclusive of them.

In the following article, we begin with a literature review outlining the empirical impetus for a project that privileges a Culturally Responsive approach to computer science learning and pedagogy. We continue with the findings from a design-based mixed-methods study that highlights how professional development that centers a critical approach to computer science and the development of cultural competence leads to the design of transformative learning experiences for girls. This article will conclude with implications for the training of computer science teachers and the development of learning ecologies that support young girls in STEM.

2. Literature Review

Culturally Responsive Computing (CRC) connects Ladson-Billings' (2014) theory of culturally relevant pedagogy (CRP) to the teaching of computing. CRP is a pedagogical approach designed to develop students' academic success, cultural competence, and sociopolitical consciousness by connecting curricular content to students' cultural understanding and real-world problem solving. Theorists suggest that using CRC in STEM learning environments can support student learning and address issues of power, race, and gender to help students (re)imagine their futures, especially for girls (Cheryan et al., 2015; Barton & Tan, 2010; Rosebery et al., 2016; Vakil, 2014). For example, Scott and White (2013) point out, "students' perception of their current cultural identities greatly influences the value they have for activities." These authors theorize that Culturally Responsive Computing (CRC) is a means to incorporate students' cultural identities into computer science teaching. Moreover, Scott et al., (2014) suggest that teachers should cultivate and establish their own cultural proficiency about students' identities and use this to build their lessons.

2.1 The Need for Culturally Relevant Pedagogies (CRP)

The National Center for Education Statistics (NCES) concluded that more than half of students of the global majority non-white races were enrolled in public schools in which less than a quarter of the students were of their own race. The NCES also reported the following regarding the minority composition of the public elementary and secondary classroom:

"In fall 2017, approximately 31 percent of public elementary and secondary students attended public schools in which the combined enrollment of minority students was at least 75 percent of total enrollment. More than half of Hispanic (60 percent), Black (58 percent), and Pacific Islander (53 percent) students attended such schools. In contrast, less than half of American Indian/Alaska Native students (39 percent), Asian students (39 percent), students of Two or more races (20 percent), and White students (6 percent) attended such schools." (NCES, 2020).

What these national statistics imply is that diversity within public schools is increasing, and the need for CRP application is becoming more crucial if schools intend to support all students' success.

The NCES also reported that in 2009, compared to boys, lower percentages of girls high school graduates reported that they liked mathematics or science (NCES, 2015). In the same year, 2009, NCES also emphasized the percentage of girls enrolled in computer/ information science was 13.8% compared to males whose percentage of enrollment was 24%. National Assessment of Educational Progress (NAEP) described the average mathematics and science scale scores of high school graduates who earned credits in STEM related technical courses, and specifically for computer/ information science in 2009, to be 155/300 for girls and 164/300 for boys (IES, 2009). These numbers and percentages indicate the lack of girls' interest and participation in computer/ information science at the high school level. Although the reasons why this gender discrepancy exists are beyond the scope of this paper, the tools of remedy and the means to create equity still need to be investigated. Often, the trend in CS/CRP research studies was to focus on the importance of enhancing girls' participation and increasing diversity in the computer science class, but the techniques on how to achieve this were not researched in depth. Our paper intends to fill that gap by emphasizing Culturally Responsive Computing (CRC) as a tool that helps construct justice between genders in computing, and increases the interest and participation of girls, as a minority group, in computer science. To understand what CRC is, it is crucial to dig deeper into one of the main foundations of this concept: Culturally Responsive Pedagogies.

Culturally Responsive Pedagogy (CRP), also sometimes called Culturally Relevant Teaching as emphasized by Ladson-Billings (1995), is a concept that originally started to research teachers who had excelled African American students. Ladson-Billings (1995) has emphasized three criteria that need to exist in the students in order to apply CRP: Students must experience academic success; students must develop and/or maintain cultural competence; and students

must develop a critical consciousness through which they challenge the status quo of the current social order. The first principle of this definition depends on the students to prove their academic accomplishment, even though they may face hostility both in and out of the classroom. In the second pillar described by Ladson-Billings (1995), the students need to show and be proud of their own culture, and the teachers should try to learn about this culture through the students; for example, some teachers allow the students to choose their own music and use their home language in the classroom. The third component of applying CRP is the critical consciousness that allows the students to be aware of what is suppressing their freedom within society and be able to criticize it and fight it back. Another definition of CRP was noted by Brown-Jeffy and Cooper (2011). They emphasized the principles of CRP as comprised of 5 main components: (1) Identity and achievement, which takes the unique culture and identity of the students into setting the curriculum, (2) equity and excellence that ensures there is equal access for all, (3) developmental appropriateness where psychological needs, motivation, collaboration, and engagement are met, (4) teaching the whole child which is equivalent to empowering the students, and finally (5) student-teacher relationship that needs to be caring and interacting (Brown-Jeffy & Cooper, 2011).

The positive effects of Culturally Responsive Pedagogy (CRP) were discussed in several research papers. Milner (2011), for example, summarized the main outcome of CRP as empowering the students. He explicates the details of the impact of CRP as follows: to empower students by allowing them to participate in the deconstruction and construction of the curriculum given to them, which in turn highlights any inequities and ultimately leads to students' academic successes. CRP also allows for the incorporation of students' culture. An incorporation which transcends the negative effects of the dominant culture and eventually creates classroom contexts that are innovative and focused on meaningful student learning (and consequently academic achievement) by strengthening the cultural competence (Milner, 2011). Other research highlights CRP's positive effects when taught at the pre-service level for teachers, stating that when teachers are encouraged to reflect on their own racial and cultural identities, there is an improvement in the connections made with diverse groups of students. (Howard, 2003; Siwatu, 2007).

2.2 Culturally Responsive Computing (CRC)

Culturally Responsive Computing emerged as a potential approach for successfully engaging marginalized and underrepresented students in technology (Scott et al, 2015). Drawing from the definition and components of Culturally Responsive (or Relevant) Pedagogy, CRC shares the same three pillars (based on Ladson-Billings' work): asset building, reflection, and connectedness. CRC builds on these pillars with a particular focus on technology education. Scott et al, (2015), defined specialized points of interest for the CRC to focus on as follows:

"(1) Motivate and improve science, technology, engineering, and math (STEM) learning experiences; (2) Provide a deeper understanding of heritage and vernacular culture, empowerment for social critique, and appreciation for cultural diversity; (3) Bring points A and B together: to diminish the separation between the worlds of culture and STEM; (4) This technology must not only respond to these identity issues, but also satisfy pedagogical demands of the curriculum."

These points need to be directed towards marginalized groups of students in order to include all the underrepresented parties in the education of technology (Scott et al, 2015). In other words, the unique cultural background of the marginalized students' needs to be understood and taken into consideration in regard to the development of the curriculum in general and the STEM classes in particular.

Culturally Responsive Computing is then a concept that is trying to include all identities (gender, culture, ethnic, religious, etc.) into consideration to improve the Computational Thinking skills of the students. The positive effects of CRC were also emphasized by several studies. Research suggests that using CRC in STEM learning environments can support student learning and address issues of power, race, and gender in order to help students in general and marginalized students specifically (re)imagine their futures (Ryoo, 2019; Barton & Tan, 2010; Ford, 2014; Rosebery et al, 2016; Morales-Chicas et al, 2019). Other research emphasized the idea that CRC supports the connection between school and community in ways that incorporate the knowledge and skills of underrepresented communities into math and computing education, while paving the direction to allow technologies to encourage education-based social movement (Lachney, 2016; Eglash et al, 2013).

Ashcraft et al, (2017) highlighted through their research on COMPUGIRLS, how the implementation of CRP positively affected girls in computing. They allowed the girls to transform from silent receivers to active contributors

in their own educational process. Roque et al. (2021), also concluded the positive effects of CRP on historically marginalized students by including both the students and their families in creative learning programs for computational construction kits by using new possibilities of their storytelling, Litts et al, (2021), also emphasized the effectiveness of using "storytelling" as a culturally responsive tool for computing. This research also emphasizes the importance of CRP, but by focusing on educating the teachers with the concepts of CRC, in order to implement CRP in their computer science classrooms. Pozos et. al. (2022) highlighted the importance of introducing justice-oriented curricula to multilingual students to be more responsive to the computational thinking materials, by using a case study approach, they were able to reach 3 principles to be used by teachers.

2.3 Importance of Intersectionality in Computer Science Class

Pournaghshband and Medel (2020) emphasized the concept of intersectionality while studying the phenomenon of girls' underrepresentation in computer science, a concept that was disregarded by other research. In the rise of diverse classrooms, girls may now be underrepresented not only because of their gender but also because of their cultural backgrounds. The merge of two or more-dimensional identities is what we refer to as intersectional identity. The authors concluded that Culturally Responsive Computing is a concept that groups all identities and hence, intersectionality is included in CRC. Intersectionality is defined as the interaction between several social identities like for example, race, class, and gender in cultivating life experiences, especially those experiences of oppression (Gopaldas, 2013; Mehrotra, 2010).

Throughout primary and secondary education, girls are underrepresented in most fields of computer science. But little research tackled how CRC can be a tool to help close the gap of underrepresentation of girls in general (especially high school girls students). For example, Searle and Kafai (2015) emphasized the positive effect CRC may have on girls from indigenous communities. They endorsed the fact that making sense to the students is a key to their success in academics in general and underrepresented girls in specific, and they also encouraged the idea of applying CRC not only in computing but also in educational crafts making activities (as a software) that can help address the "identity gap" for girls and students from non-dominant backgrounds (Searle & Kafai, 2015). A point also tackled by Corkin et al, (2020), who examined the extent to which an intervention informed by culturally relevant pedagogy theory predicted the motivation of underrepresented high school students to take computer science courses.

Culturally Responsive Computing is considered to be a means that can be used by students to understand their own intersectionality and by teachers in order to better understand their students' unique identities. The general aim of this research is to emphasize the positive effects of teaching computer science teachers the principles of CRC for the implementation of CRP and the improvement of the classroom culture, and the inclusion of marginalized minorities, especially girls. We used a systematized way to implement CRC by infusing transformative learning for the teachers through the use of a DRB. The implementation will be emphasized in the method section.

3. Method

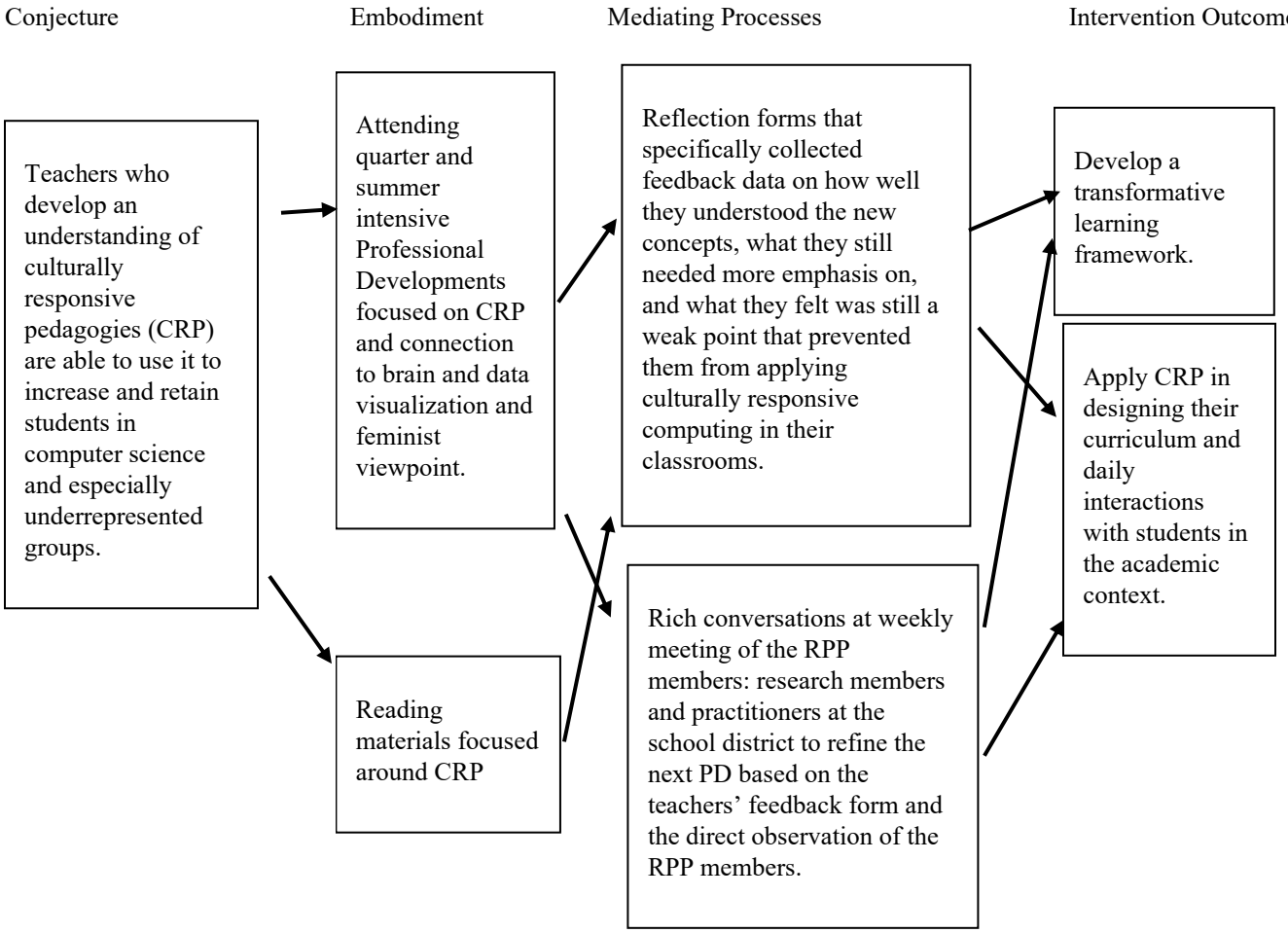
This paper is a result of the collaboration between researchers and practitioners in the context of a Design-Based Research framework. Researchers have argued that the RPP model is effective because "collaboration is one of the best ways to close the research/practice gap and propel more evidence-based practice (Murray, 2017)" and also because the communication between researchers and practitioners can be the most beneficial for the two communities, although the researchers part still carry the lion's share (Sato & Loewen, 2022). We conducted a mixed methods study of six CS teachers (all from the same school district) over a two-year period. Data sources consisted of in-depth interviews and focus groups. Pre- and post-surveys were also administered, where respondents answered both demographic questions and self-identified their culturally responsive pedagogical practice The in-depth interviews were conducted at the beginning of the first year, and approximately at the same time, the teachers were asked to fill out the online survey. The research team introduced various concepts to the teachers over the course of the two years through quarterly sessions of Professional developments and trainings that included culturally responsive computing, the relationship with the brain, data feminism visualization, simulations and hackathons. At the end of the second and last year, focus groups were conducted and the post-survey was administered to the teachers.

3.1 Design Based Research

As a Social Design Based Experiment (Gutierrez & Jurow, 2016) we engaged in concerted side-by-side stakeholder participation in all aspects of the project. Importantly, we were keenly aware of how teachers influence the learning process of the students the most, putting theory into practice to alter their methods in the classroom. Since we are aware that a one size fits all mentality, will not serve the students especially when learning computer science and STEM in general, a design-based research allowed the teachers to reflect on new information and material given to them through mutual relations of exchange; and in this case the culturally responsive computing that takes into consideration and prioritizes the unique characteristics of the students (Gutierrez & Vossoughi, 2010). In order to create the desired outcomes, the research team became a central part of the teachers' learning ecology, by first being points of contact for any inquiry throughout the research and second by designing professional development opportunities that helped to develop the new enactment for transformative learning.

In our work we considered how design is a re-mediating activity (see Gutiérrez, 2018) that consists of making a shift in the way the entire ecology for learning (contexts, tools, relationships, etc.) must be engaged in order to address learning at a systemic level. Thus, we went beyond emphasizing the development of technical disciplinary skill(s) for our teacher participants, but we instead tried to shift their way of thinking on how they viewed their students in general and the students who identified as girls in particular. We were keen on collecting the teachers' thoughts and feedback after each Professional development (see Figure 1 below)

Figure 1: Conjecture Map*



*Based on the work of Sandoval (2014)

3.2 Participants

Six computer science teachers (N=6; three males and three females) participated in the study. All Six participants were given numbers and pseudonyms, i.e., teacher 1: Robert, teacher 2: Catherine, etc. (see table 5 for participants' demographics). Throughout the two-year period, the teachers received CRC training, with a focus on equity in computer science (CS) for girls to support teachers' instruction of rigorous CS content to their girl and underrepresented students. The ages of the participants at the time of the research ranged from 36 to 62 years old. All the teachers had five or more years' of experience. Four teachers taught in Title I schools (see Table 1).

Table 1. Teachers' demographic at the time of the research

Teacher number	Pseudonym	Gender	Age	Years of Experience
Teacher 1	Robert	Male	58	5 years and more
Teacher 2	Catherine	Female	62	5 years and more
Teacher 3	Caleb	Male	47	5 years and more
Teacher 4	Luna	Female	50+	5 years and more
Teacher 5	George	Male	46	5 years and more
Teacher 6	Julia	Female	36	5 years and more

4. Data Collection and Procedures

This mixed methods study of six computer science teachers conducted over two years examines the effects of Culturally Responsive Computing (CRC) on student engagement and teachers' knowledge of their girls and underrepresented students' needs focusing on their identity and intersectionality. Qualitative data sources include in-depth interviews and focus groups. Quantitative data was collected via a survey.

4.1 The Qualitative Part

4.1.1 The Interviews

Participants were interviewed virtually through Zoom for an average of two hours per interview. Based on previous interview methods recommendations ((Velardo and Elliott, 2021), each semi-structured interview had one interviewer from the research team, in addition to a silent observer, also from the research team, who was taking field notes and attending the interview silently, i.e., with their camera and audio off. The focus of the in-depth interviews was to explore ways that the teachers handle students' unique identities and intersectionality (including gender, culture, language, and race) and how they affirm this uniqueness. There was also a focus on learning if and how teachers help students to develop pride, confidence, and healthy self-esteem without denying the value and dignity of others, and their perceptions and techniques that strengthen diversity in the classroom. Questions included teachers' recruitment strategies, especially with girls in their ICT programs and how they apply equity and social justice in their classroom, specifically in regard to their (intersectional) gender and social identities. The opinions on PDs and how they affected their teaching strategies were also discussed.

4.1.2 The Focus Group

Two focus groups were conducted virtually via Zoom and had an average of 3-4 participants. Similar to the interviews, the focus groups were semi-structured, and lasted for almost two hours. The focus groups mainly emphasized teachers' strategies in applying equity in their classrooms with regard to the differences in culture, and how they addressed the issues of gender in Computer Science.

4.1.3 The Transformative Learning Part

The transformative learning consisted of 4 quarterly Professional Developments (PD), and one summer intensive session over the course of two years. The PDs were two hours long each, and the summer intensives were 4 hours each for a period of 5 days. The PDs were developed by the research team: The Principal investigator, who is an expert in culturally responsive pedagogies, the co-PI who is an expert in computer science, two research assistants

and one research coordinator. The team at the school's district was also involved in every step of the transformative learning process. The PDs focused on explaining the concepts of Culturally Responsive Computing, the relationship with the brain and data visualization. The first summer intensive focused on an introductory background in data science including the analytical pipeline of data collection processing, analysis, and data visualization. The second summer intensive focused on relating data visualization through a data feminist viewpoint (authors, 2021). The main goal was to relate the concepts of computing to culturally responsive pedagogies that specifically frame girls and their unique ways of understanding the data, through re-mediating activities, by emphasizing contradictions, history, and equity. Each PD gave the teachers' participants the chance to reflect and re-mediate by filling in a feedback form. This form highlighted the new concepts they were able to grasp, what they still needed more emphasis on, and what they felt was still a weak point that prevented them from applying culturally responsive computing in their classrooms.

As detailed by authors (2021), the design of the professional development week is to teach the participants data science by applying 3 data feminist principles, by incorporating them into the lessons plan. with the aims to alter the traditional approach by following the three tenants summarized as follows: "1) invent new ways to represent data unknowns, 2) invent new ways to reference the material economy behind the data, 3) make dissent possible." The five days planned by the research team included activities ranging from data science, community building, and discussions.

4.2 The Quantitative Part: The Survey

The participants completed two online surveys: the pre-test, at the beginning of the first year, then the post-test at the end of the second year. The pre-surveys were administered before the transformative learning part took place; we wanted to quantitatively test if there was any improvement to the teachers' knowledge before and after they were exposed to the culturally responsive computing PDs.

4.2.1 The Online Survey

The survey was adapted from a CRP rubric created by the Centennial School District in Oregon. This district has one of the highest numbers of homeless students at a percentage of 1.6%. The original survey: Centennial School District Culturally responsive rubric, which had 4 main sections: planning and preparation, the classroom environment, instruction and professional responsibilities. We recreated the survey with a focus on measuring the teachers' culturally responsive pedagogical knowledge, and the degree of its application in the classroom with their students. Our survey aimed to measure specific factors, as illustrated in table 2.

Table 2. Factors components of the teachers' survey

Factor 1: Knowledge of child and adolescent development	Factor 2: Knowledge of the learning process
Factor 3: Knowledge of students' skills, knowledge, and language proficiency	Factor 4: Knowledge of students' interests and cultural heritage
Factor 5: Knowledge of students' diverse needs	Factor 6: Knowledge of content related pedagogy
Factor 7: Appropriateness for diverse learners	Factor 8: Resources for classroom use
Factor 9: Resources to extend content knowledge and pedagogy	Factor 10: Resources for students
Factor 11: Teacher interactions with students	Factor 12: Student interaction with other students
Factor 13: Expectations for learning and achievement	Factor 14: Teacher creates an environment that promotes pride in work
Factor 15: Student engagement	

4.2.2 Cronbach's Alpha Reliability Test

A Cronbach's Alpha test was run for each Likert Scale item within the pre and post teachers' survey to determine the internal consistency and whether it could produce reliable composite scores. The higher α coefficient > 0.6, the more the items have shared covariance and probably measure the same underlying concept. Results showed Alpha α in all of the category variables is > 0.6, which means the test has high internal consistency and acceptable index (Nunnally and Brenstein, 1994). The Pre survey yielded an alpha value of ά =0.824 >0.6. (Table 3).

Table 3. Test Cronbach's alpha, Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.824	.803	15

5. Data Analysis

Data analysis of the impact of teacher transformative learning on the implementation of CRC was performed. Qualitative data concerning the interviews was analyzed first, due to the fact that this was the first data collection method used. We then analyzed the two focus groups, and lastly conducted the quantitative analysis using the paired sample T-test after having the data from the pre and post-surveys. We relied on Corbin and Strauss' (2008) constant comparative method of grounded theory. Open and axial coding were used to classify concepts and codes under various categories to extract emergent themes (Creswell, 2014). Some of the main themes and codes we discovered in the interviews with our 6 teachers participants were: Girls' recruitment strategies, girls learning styles, teachers' styles to support students, equity and justice in computer science classes, gender and sexism in computer science classes, cultural and race identities, types of support to help the teachers. From the focus groups, other themes were revealed like for example: gender, sexism and girls in computer science, Difficulties with Discussion of Gender/Sexism in computer science, challenges girls face in computer science classes, challenges minority groups to face in computer science classes, Curriculum Changes to Build Culture of CS where Girls Feel a Part of, Extracurricular Changes to Build Culture of CS where Girls Feel a Part of, the district's role to build Culture of CS where Girls Feel a Part of.

Preliminary findings and generalizations were extracted from the analysis and then compared to the existing literature. Transcripts were edited for mistakes and consistency of definitions of codes. Researchers' reflexivity, position, and biases were discussed for reliability and peer debriefing and member-checking were used for trustworthiness. (Creswell, 2014; Denzin & Lincoln, 2011). The transformative part took place after the pre-survey was administered, and right after the first batch of individual interviews. After each Professional development, a feedback form was administered to the teacher and included a part on what was most/ least useful, and are you ready to use CRC in your classroom, and if not what is still missing. We used the information from the feedback forms to develop the next PD session in a way that tackled the missing and lacking points emphasized by the teachers. The pre- and post-survey results were first transferred from Qualtrics to SPSS, and from there, a Paired sample T-test was analyzed to measure any increase in the Means of the factors components of the survey (Table 4). Because we were using the same test on the same sample, the paired sample T-test seemed the most suitable means of statistical analysis.

Table 4. Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-Knowledge of child and adolescent development	2.67	6	.516	.211
	Post-Knowledge of child and adolescent development	3.00	6	.000	.000
Pair 4	Pre-Knowledge of students' interests and cultural heritage Click to write the question text	2.67	6	.516	.211
	Post-Knowledge of students' interests and cultural heritage Click to write the question text	3.00	6	.000	.000
Pair 10	Pre-Resources for students	2.50	6	1.225	.500
	Post-Resources for students	3.00	6	1.095	.447
Pair 15	Pre-Student engagement	2.83	6	1.169	.477
	Post-Student engagement	3.33	6	.816	.333

6. Results and Discussion

We triangulated the quantitative and qualitative data to develop a deeper and richer understanding of the impact of CRC on teachers. A paired sample t-test was conducted to compare teachers' knowledge of CRC before and after the training. The results suggested that the mean of Four Factors increased, which indicates an improvement resulting from the CRC training provided to the teachers, and their knowledge increased, which also confirms the results by Leonard and Sentance (2021).

6.1 Knowledge of Child and Adolescent Development

We found an increase in the mean for the Knowledge of Child and Adolescent Development factor, IV (Independent Variable) level 1 (M= 2.67, SD= 0.516), and IV level 2 (M= 3.00, SD= 0.00). This indicates that teachers' knowledge of the developmental characteristics of their students improved including the impact of students' race, gender, and culture on their development. The increase in this factor highlights the teachers' deeper understanding of how the identities and cultures of the students affect their growth. This is an integral component of CRC. Before the CRC training, teachers did not express the need to incorporate their knowledge of their diverse students into their teaching. For example, Robert mentions:

"Yeah, my class is very diverse. I have one Caucasian girl in my class and everybody else of every other race on the planet. And I don't have to work very hard at the cultural part. Sometimes I have to work hard about maybe getting them to work in different groups, but they kind of get a little, they have little packs of three, four, five kids and they kind of just work together and I don't, I don't try to monitor. I just see what's going on in the classroom. I don't have to work very hard at the cultural part."

As Robert's comment reveals, prior to the professional development, the teachers participating in this study were aware of the diversity in their classrooms. However, the in-depth interviews and focus groups showed that they did not explicitly address the various needs of their diverse learners before the professional development, nor did they acknowledge the deeper need to focus on their students' race and culture. The reasons they mentioned were that they

did not think it was important or because they did not have enough background to start this conversation with the students.

6.2 Knowledge of Students' Interests and Cultural Heritage

We noticed an increase in the mean of the Knowledge of Students' Interests and Cultural Heritage factor, IV level 1 (M= 2.67, SD= 0.516), and IV level 2 (M= 3.00, SD= 0.00). Teachers had an increased recognition of the importance of understanding their students' interests and cultural heritage. Additionally, teachers also revealed that they understood the importance of knowing the individual needs of their diverse students in general, and their girl students. A problem that exists, as discussed by Scott et al., (2014) is the obvious gap in the CRC theory that leaves out cultural identity, and instead focuses on technical literacies. This practice sidelines minoritized groups from being engaged by the pedagogies. Our teachers, too, experienced discomfort when talking about culture. According to Robert, "That's always been hard to try to wiggle those in there." Caleb, also, had a similar response:

"I don't know that I necessarily [discuss diversity] explicitly. I guess I should. But I don't actually get into that topic. I pretty much stay with 'this is the code we're going to use,' and I demonstrate it. […] I don't spend a lot of time in my classes with, you know, expressing that topic other than to tell them what my experience was when I went to college."

We found that after the teachers received the CRC training, teachers are more aware of the different interests of the students and their diverse cultural heritage, resulting in serious efforts to encourage girls and accommodate their special interests. Catherine points out her experience by comparing her awareness levels before and after the PD by explaining:

"Before the PD I think I was less aware of the situation. I've always known that there was a […] lack of participation by girls, but I think that being part of what I call the program, has caused me to think more and be more aware every day when I teach. So, I try to relate what I learn from this [PD] and try to apply as much as I can, where I feel comfortable. […] before I feel like I couldn't. " The teachers' remarkable increasing awareness of the diverse needs, cultures and interests of their students is reflected in their interaction with them.

6.3 Resources for Students

The mean of the Resources for Students factor also increased, IV level 1 (M= 2.5, SD= 1.225) and IV level 2 (M= 3.00, SD= 1.095). Teachers showed improved knowledge of resources that appropriately reflect the gender identity and gender diversity of their students, including those available through the school or district, in the community, and on the internet. After the training, teachers were convinced of the need for different resources to accommodate students from various cultures. They were consequently ready and willing to search for additional resources to engage their diverse students. Robert, for example, who, at the start of this research did not feel comfortable discussing students' identities, added cultural resources by inviting different speakers to his classroom.:

"So, I'm trying to embrace [my students'] differences, and you know, the biggest way is not made in the regular classroom setting, but I guess it's more about people that my speakers talk about. These are the qualities they may have that people don't realize that aren't being, they're not being pronounced in the class of being coding, but in the workplace, those differences which could be very valuable." The teachers embrace their students' differences by searching for resources to accommodate their various cultural differences.

6.4 Student Engagement

The mean of the Student Engagement factor increased; IV level 1 (M= 2.83, SD= 1.169) and IV level 2 (M= 3.33, SD= 0.816). Teachers effectively employed strategies to ensure that all voices are heard in their classrooms. Teachers' focus on engaging all the students in the classroom increased after the CRC training. Specifically, teachers focused on engaging girls:

"[The PD] helped to force me out of my shell, to talk more to the students and try to get their personalities to shine through. And acknowledge those who are sharing both in the chat and by speaking. And I think, in a virtual environment it helps all students, both male and female to feel comfortable to share because they can share either as

a group where they can share independently or privately to the teacher. So, I think that's really helped. I have noticed from last year to this year, an increase in female enrollment and I'm hoping that that trend just continues."

Overall, we discovered ways CRC raised teachers' awareness of diversity. Julia explains how the PD made her look for more diversity in the classroom, and search to add more diverse students and engage them because of how she came to believe this enriches the teaching experience. She exemplifies this by saying:

"It definitely made me think a lot about what I'm doing. […] So, I've always noticed that, you know, I like to get a lot more diversity in my classroom. And it definitely made me think about it a lot more. And I'm trying to, I'm still, feel like I have a long way to go, but. They definitely opened my eyes a little more."

Therefore, we uncovered that incorporating CRC practices into CS instruction engages diverse students in general and girls. CRC supports the interactions between teacher/ student and student/ student because it results in understanding students 'differences and shaping the CS content to address their diverse needs.

7. Scientific Significance of the Study

This study reveals that training in Culturally Responsive Computing (CRC) positively affects teachers' ability to engage girls in computing (see figure 1 for the conjecture map). Our results also align with Scott et al., (2014), who emphasize the obvious gap in the CRC theory that leaves out cultural identity, and instead focuses on technical literacies. Teachers' knowledge of child and adolescent development, knowledge of students' interests and cultural heritage, their willingness to expand the various resources that respect the students' differences, and increased students' engagement highlight the importance of training teachers in CRC. We see this research as confirming the importance of CRC or the use of culturally responsive pedagogies in computer science, which comes in accordance with Brown et al, (2019), who also endorsed in their research the importance and positive effects of teaching CRP to STEM teachers. Transformative learning in the form of social design research allowed the teachers to better understand and acknowledge the students' intersectionality by learning about their diverse cultures, ethnicities, and backgrounds and how it affects their social and academic development. This creates a positive and inviting classroom culture that results in more equitable opportunities for the students' learning, especially marginalized and underrepresented ones like girls in the STEM area.

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References

Ashcraft, C., Eger, E., & Scott, k. (2017). Becoming technosocial change agents: Intersectionality and culturally responsive pedagogies as vital resources for increasing girls' participation in computing. Anthropology & Education Quarterly, 48(3), 233–251. http://doi.org/10.1111/aeq.12197

Barton, A. C., & Tan, E. (2010). We be burnin'! Agency, Identity, and Science Learning. The Journal of the Learning Sciences 19(2), 187-229.

Baynes, A & Norris, A. (2021). Professional development for high school computer science teachers on data science through a Feminist Lens. IEEE Frontiers in Education Conference (FIE), 1-5, http://doi.org/10.1109/FIE49875.2021.9637249

Brown, A. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. The Journal of the Learning Science, 2(2), 141-178.

Brown, B., Boda, P., Lemmi, C., & Monroe, X. (2019). Moving culturally relevant pedagogy from theory to practice: Exploring teachers' application of culturally relevant education in science and mathematics. Urban Education, 54(6), 775-803. http://doi.org/10.1177/0042085918794802

Brown-Jeffy, S., & Cooper, J. (2011). Toward a conceptual framework of culturally relevant pedagogy: An overview of the conceptual and theoretical literature. Teacher Education Quarterly, 65-84. Retrieved from: https://files.eric.ed.gov/fulltext/EJ914924.pdf

Centennial School District 28J. Revised Culturally Responsive Teacher Rubric. Fully Revised Culturally Responsive Danielson Rubric (csd28j.org)

Cheryan, S., Master, A., & Meltzoff, A. N. (2015) Cultural stereotypes as gatekeepers: Increasing girls' interest in computer science and engineering by diversifying stereotypes. Frontiers in psychology, 6(49). https://doi.org/10.3389/fpsyg.2015.00049

Corbin, J., & Straus, A. (2008). Basics of qualitative research (3rd ed.). Sage.

Creswell, J. W. (2014). Research design: Qualitative, Quantitative, and mixed methods approaches (4th ed.). Sage.

Denzin, N. K., & Lincoln, Y. S. (2011). The sage handbook of qualitative research. Sage.

Eglash, R., Gilbert, J., Taylor, V., & Geier, S. (2013). Culturally responsive computing in urban, after-school contexts: Two approaches. Urban Education, XX(X), 1-28. http://doi.org/10.1177/0042085913499211

Gopaldas, A. (2013). Intersectionality 101. Journal of Public Policy & Marketing, 32 (Special Issue), 90–94

Goode, J., Chapman, G., & Margolis, J. (2012). Beyond curriculum: the exploring computer science program. ACM Inroads, 3(2), 47-53.

Gutiérrez, K. D. (2008). Developing a sociocritical literacy in the third space. Reading research quarterly, 43(2), 148-164.

Gutiérrez, K & Vossoughi, S. (2010). Lifting off the ground to return anew: Mediated praxis, transformative learning, and social design experiments. Journal of Teacher Education 61(1-2) 100–117. http://doi.org/10.1177/0022487109347877

Gutiérrez, K. D., & Jurow, A. S. (2016). Social design experiments: Toward equity by design. Journal of the Learning Sciences, 25(4), 565-598.

Gutiérrez, K. D. (2018). Social design–based experiments: A proleptic approach to literacy. Literacy Research: Theory, Method, and Practice, 67(1), 86-108.

Howard, T. (2003). Culturally relevant pedagogy: Ingredients for critical teacher reflection. Theory into Practice, 42(3), 195-202.

Kimberly A. Scott, Kimberly M. Sheridan & Kevin Clark (2014) Culturally computing: A theory revisited, Learning, Media and Technology, 40(4), 412-436, http://doi.org/10.1080/17439884.2014.924966

Ladson-Billings, G. (2014). Culturally Relevant Pedagogy 2.0: a.k.a. the Remix. Harvard Educational Review, 84(1), 74–84. http://doi.org/10.17763/haer.84.1.p2rj131485484751

Ladson-Billings, G. (1995). But that's just good teaching! The case for culturally relevant pedagogy. Theory into Practice, 34(3). 159-165. Retrieved from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.676.4239&rep=rep1&type=pdf

Lachney, M. (2016). Culturally responsive computing as brokerage: Toward asset building with education-based social movements. Learning Media and Technology, 42(4), 420-439, http://doi.org/10.1080/17439884.2016.1211679

Leonard, H. C., & Sentance, S. (2021). Culturally-relevant and responsive pedagogy in computing: A Quick Scoping Review. International Journal of Computer Science Education in Schools, 5(2), 3–13. http://doi.org/10.21585/ijcses.v5i2.13

Litts, B., Searle, K., Brayboy, B., & Kafai, Y. (2021) Computing for all: Examining critical biases in computational tools for learning. British Journal of Educational Training. 52(2). 842-857. http://doi.org/10.1111/bjet.13059

Mehrotra, G. (2013). Toward a continuum of intersectionality theorizing for feminist social work scholarship. Journal of Women and Social Work, 25(4), 417-430. http://doi.org/10.1177/0886109910384190

Milner IV, H. (2011). Culturally relevant pedagogy in a diverse urban classroom. Urban Re, 43, 66-89. http://doi.org/10.1007/s11256-009-0143-0

Morales-Chicas, J., Castillo, M., Bernal, I., Ramos, P., & Guzman, B. (2019). Computing with relevance and purpose: A review of culturally relevant education in computing. International Journal of Multicultural Education, 21(1), 125. http://doi.org/10.18251/ijme.v21i1.1745

Murray Law, B. (2017). Pillars of a Researcher-Practitioner Partnership. ASHA Leader, 22(8), 64. Retrieved from http://proxy.lib.csus.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=124286161

National Center for Education Statistics (2020), Racial/Ethnic Enrollment in Public Schools, chapter one, retrieved from: http://nces.ed.gov/programs/coe/pdf/coe_cge.pdf

National Center for Education Statistics (2015), Gender differences in science, technology, engineering, and mathematics (STEM) interest, credits earned, and NAEP performance in the 12th Grade. Stats in Brief, 075. Retrieved from: http://nces.ed.gov/pubs2015/2015075.pdf

Nunnally, J.C., & Bernstein, I.H. (1994). The assessment of reliability. Psychometric Theory, 3, 248-292.

Pournaghshband, V., & Medel, P. (2020). Promoting diversity-inclusive computer science pedagogies: A multidimensional perspective. Association for Computing Machinery, Innovation and Technology in Computer Science Education (ITiCSE) '20, June 15–19, 2020, Trondheim, Norway. http://doi.org/10.1145/3341525.3387360

Pozos, R., Severance, S., Denner, J., & Tellez, K. (2022). Exploring design principles in computational thinking instruction for multilingual learners. Teachers College Record 124(5). DOI: http://doi.org/10.1177/01614681221104043

Roque, R., Tamashiro, M.A., Mcconnell, K., & Granados, J. (2021). Opportunities and limitations of construction kits in culturally responsive computing contexts: Lessons from Scratch Jr. and family creative learning. Interaction Design and Children (IDC '21), June 24–30, 2021, Athens, Greece. ACM, New York, NY, USA. http://doi.org/10.1145/3459990.3460728

Rosebery, A. S., Warren, B., & Tucker-Raymond, E. (2016). Developing interpretive power in science teaching. Journal of Research in Science Teaching, (10), 1571. http://doi.org/10.1002/tea.21267

Ryoo, J. J. (2019). Pedagogy that Supports Computer Science for All. ACM Transactions on Computing Education, 19(4), 1–23. http://doi.org/10.1145/3322210

Sandoval, W. (2014). Conjecture mapping: An approach to systematic educational design research. Journal Of The Learning Sciences, 23(1), 18-36.

Sato, M., & Loewen, S. (2022). The research–practice dialogue in second language learning and teaching: Past, present, and future. The Modern Language Journal, 106(3), http://doi.org/10.1111/modl.12791 0026-7902/22/509–527

Scott, K. A., & White, M. A. (2013). COMPUGIRLS' standpoint: Culturally responsive computing and its effect on girls of color. Urban Education, 48(5), 657–681. Retrieved from: http://journals.sagepub.com/doi/pdf/10.1177/0042085913491219

Scott, K., Aist, G., & Zhang, X. (2014). Designing a culturally responsive computing curriculum for girls. International Journal of Gender, Science and Technology, 6(2), 264- 276. Retrieved from: http://genderandset.open.ac.uk/index.php/genderandset/article/view/361

Scott, K., Sheridan, K., & Clark, K. (2015). Culturally responsive computing: A theory revisited. Learning Media and Technology, 40(4), 412-436. http://doi.org/10.1080/17439884.2014.924966

Searle, K., & Kafai, Y. (2015). Culturally responsive making with American Indian girls: Bridging the identity gap in crafting and computing with electronic textiles. GenderIT '15: Proceedings of the Third Conference on GenderIT, 9–16. http://doi.org/10.1145/2807565.2807707

Siwatu, K. (2007). Preservice teachers' culturally responsive teaching self-efficacy and outcome expectancy belief. Teaching and Teacher Education, 23, 1086–1101. http://doi.org/10.1016/j.tate.2006.07.011

Vakil, S. (2014). A critical pedagogy approach for engaging urban youth in mobile app development in an after-school program. Equity & Excellence in Education, 47(1), 31-45.

Velardo, S., & Elliott, S. (2021). Co-Interviewing in qualitative social research: Prospects, merits and considerations. International Journal of Qualitative Methods, 20, http://doi.org/10.1177/16094069211054920

Vetter, A., Faircloth, B. S., Hewitt, K. K., Gonzalez, L. M., He, Y., & Rock, M. L. (2022). Equity and social justice in research practice partnerships in the United States. Review of Educational Research. DOI: http://doi.org/10.3102/00346543211070048