Teacher Perceptions of Equity in High School Computer Science Classrooms

NINGER ZHOU, YUCHENG CAO, and SHARIN JACOB, School of Education, University of California, Irvine
DEBRA RICHARDSON, Donald Bren School of Information and Computer Science, University of California, Irvine

Effective and equitable CS teaching is contingent on teachers' robust understanding of equity issues in CS classrooms. To this end, this study examined high school teachers' perceptions of equity during their participation in a CS teacher certificate program over two years. The participants are from various disciplines and from schools that serve under-represented students. Using a qualitative approach, we conducted content analysis of the teachers' written reflections and responses to semi-structured interviews. Based on the justice-centered framework, we analyzed the major themes that emerged from the content analysis. The findings provide insights into high school CS teachers' understanding of equity, the strategies that teachers use to address equity issues, and how teachers interpret the causes of inequities in CS classrooms. This research presents frameworks for examining teachers' conceptualizations of equity and can inform the implementation of future professional development programs for CS teachers.

CCS Concepts: • **Social and professional topics** → **Computer science education**; **K-12 education**; Accreditation;

Additional Key Words and Phrases: Computer science, equity, secondary education, teacher professional development

ACM Reference format:
Ninger Zhou, Yucheng Cao, Sharin Jacob, and Debra Richardson. 2020. Teacher Perceptions of Equity in High School Computer Science Classrooms. *ACM Trans. Comput. Educ.* 20, 3, Article 24 (August 2020), 27 pages.
https://doi.org/10.1145/3410633

1 INTRODUCTION

In the past decade, efforts devoted to addressing equity issues in CS education have shown a strong focus on access, largely exemplified as broadening the participation of underrepresented students in CS education programs [2]. Propelled by national initiatives such as CS10K, innovative and

A small portion of this work has been published in a conference proceeding, Zhou et al., 2018, and has been revised extensively in the current version. The changes are much greater than the 30% requirement set by the journal.
This work was supported by the National Science Foundation grant no. 1640247 and the NSF Research Experiences for Undergraduates (REU) program.
Authors' addresses: N. Zhou, Y. Cao, and S. Jacob, School of Education, University of California, Irvine, Irvine, CA, 92697; emails: znenancy@gmail.com, {yuchc10, sharinj}@uci.edu; D. Richardson, Donald Bren School of Information and Computer Science, University of California, Irvine, Irvine, CA, 92697; email: djr@ics.uci.edu.

1946-6226/2020/08-ART24 $15.00
https://doi.org/10.1145/3410633

high-quality CS curricula have been developed to engage students from diverse backgrounds and facilitate their understanding of essential CS concepts [4, 33]. However, access constitutes only one of the myriad facets of equity issues involved in CS education [8, 36]. Conceptualizing equity with an overemphasis on equal access to CS resources risks obscuring the more fundamental socio-cultural and systemic aspects of equity [7]. There has been growing consensus on the importance of helping educators go beyond access and form a deeper understanding of equity issues and equitable practices [8, 22, 39]. To this end, we examined in-service high school teachers' understanding of equity issues during their participation in one of the first CS teacher certificate programs in the nation. In this study, through the lens of the justice-centered framework, we identified the major themes that emerged from teacher interpretations of equity issues in CS education. Findings from this study can inform the design of future CS teacher professional development (PD) programs as well as certificate programs aimed at promoting teacher conceptualizations of equity in CS education settings.

In this study, we address the following research questions:

1. What are teachers' understandings of equity issues in high school CS classrooms?
   a. What are teachers' general understandings of equity issues in CS classrooms after attending a Teaching Exploring Computer Science PD course?
   b. How do teachers understand equity issues in CS classrooms in the context of their school environment?
2. What are the strategies that teachers use to address equity issues in high school CS classrooms?
3. How do teachers perceive the causes of inequities in high school CS classrooms?

2 BACKGROUND

2.1 Equity in CS Education

Equity issues in CS education have been widely observed and documented as underrepresented students having unequal access to computing tools and learning opportunities [2, 20, 33]. In recent years, national initiatives and research efforts have focused on addressing such access-related issues through establishing evidence-based CS curriculum and enrolling diverse students into CS classrooms [2, 4]. However, equity issues are deeply rooted in social and cultural practices and go far beyond creating equal access to resources and learning opportunities [31]. For example, research from the more long-standing field of science education has suggested that creating equitable learning environments involves valuing the students' cultural experiences, aligning students' cultural and linguistic resources with teaching practices, and interpreting knowledge in accordance with students' cultural backgrounds [31].

Additionally, recent research in both CS and science education has suggested the necessity to go beyond access and pay attention to the cultural and societal factors that contribute to equitable participation [2, 36, 38, 39]. For example, socio-cultural stereotypes about what types of students can excel in CS may limit the development of students' self-efficacy in CS due to social persuasion [3], which in turn impacts students' motivation and learning outcomes [33]. As such, besides access, equity in CS education should encompass the social, cultural, and historical contexts of teaching and learning.

2.2 The Uniqueness of Equity Issues in CS Education

In the context of CS education, equity issues can be particularly challenging. Despite its relatively short history, CS has ubiquitous applications in our daily life [23]. With the interactive systems in CS applications, students can acquire implicit CS knowledge including automation, abstraction,

or programming without external guidance [5, 16]. In contrast, for math and science, students are not likely to acquire substantial knowledge without formal schooling [1, 28]. Thus, compared with traditional subject areas, CS is a unique discipline where students may demonstrate prior knowledge at strikingly different levels upon first entering classrooms [20], creating challenges for teachers to implement equitable practices.

Furthermore, students' diverse social-cultural backgrounds can pose unique challenges to equity in CS classrooms [21, 33]. Previous research has emphasized connecting with students' social and cultural backgrounds to facilitate meaningful CS learning and empowering communities [21, 22, 41]. However, CS as a discipline is innately complex and filled with multi-solution problems [36], where few methods exist to gauge the potential of students' problem-solving strategies in CS [15]. As a result, it is challenging for educators to maintain an equitable stance, because it may appear that "some groups of students just will not get it," while in fact the students are approaching the problem from a different and original perspective based on their cultural backgrounds and community experiences [41]. Therefore, to promote equity in CS classrooms, it is important for teachers to develop an in-depth understanding of students' backgrounds and recognize that all students can become effective CS problem-solvers given sufficient time and support.

Last, the political dimension of CS education has a unique impact on equity. On the macro level, we are now in an era when people equipped with computing skills are more likely to have power and professional opportunities in various social realms [23, 50]; on the micro level, the learning of computing skills requires access to technology, resources, and educational experiences not available to all communities. The students are thus faced with a dilemma: CS learning generates social power and it is at the same time influenced by such power. In addition, previous research has called for closer examinations of the political dimensions of teaching, which often involves implicit and explicit values upheld by groups in power, such as the types of individuals who can excel in the field and the sorts of practices worth teaching [39]. Without realizing the political aspects of teaching, we may risk exacerbating the oppression and inequities already manifested in the discipline. As a result, researchers have argued that CS education is political in nature [39, 50] and have proposed using a justice-centered framework to examine equity issues in CS education and go beyond the focus on access [50].

2.3 The Justice-centered Framework for Conceptualizing Equity

2.3.1 The Redistributive and the Relational Model. Although research on the justice-centered framework has been limited in CS education, recent work from other fields such as science education has explored this framework extensively [7, 8, 38, 39]. The science education literature on equity has proposed the redistributive and the relational model, which spans over a spectrum of socially just practices [8]. While the equal distribution of resources, or the redistributive model, leans towards the weak inclusion end of the spectrum, the valuing of student differences in the context of equity, or the relational model, gravitates towards the strong inclusion end of the spectrum [8]. Built on the critical theory, the spectrum view differentiates the focal point of equity practices: making changes to individuals or to social structures. For instance, equity practices on the weaker inclusion end of the spectrum may take the form of enrolling more female students in CS programs, which focuses on making changes to the status of female students as individuals. In contrast, strong inclusion equity practices focus on exploring the power of individuals and how cultures in CS education can be changed to accommodate and respect the differences of individuals [24]. Seeing equity as a spectrum of socially just practices has the advantage of attending to both access and the more fundamental realms beyond access, such as social structures and cultural practices. However, to recognize the multifaceted dimensions of the justice-centered framework

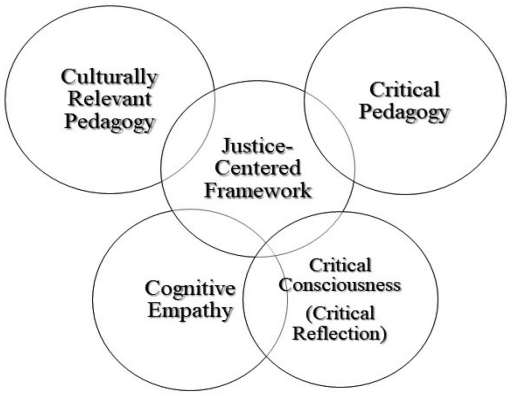

Fig. 1. Justice-centered framework draws on the culturally relevant pedagogy and critical pedagogy. Critical consciousness is an integral part in the justice-centered framework. Cognitive empathy, an indispensable component in human consciousness, may have important roles in critical consciousness and by extension the justice-centered framework.

and enact socially just practices on the strong inclusion end of the spectrum, educators need to be critically conscious about the roles of individuals and social systems in equity.

2.3.2 Critical Reflection of Individual vs. Structural Attributions. As shown in Figure 1, drawing on critical pedagogy and culturally relevant pedagogy, justice-centered pedagogy theorizes teaching as a mechanism to "disrupt the role of school as the producer of inequities" [38, p.1036]. To achieve this goal, justice-centered pedagogy advocates that "(a) students must experience academic success, (b) students must develop and/or maintain cultural competence, and (c) students must develop critical consciousness through which they challenge the status quo of the current social order" [30, p.160]. The critical consciousness construct highlighted in (c) has been defined as the idea that individuals become critically aware of the conditions of oppression and take action to implement change to these conditions [51]. Previous research has argued that critical consciousness, which includes critical reflection, political efficacy, and critical action, should be an integral part of teacher professional development [19].

In this study, we focus on critical reflection, the process of analyzing the causes of inequities in racial groups, socioeconomic status, and gender in a given domain. According to attribution theory in social psychology, when people engage in critical reflection, they may attribute social inequities to structural or individual factors [51]. In general, individuals with higher level of critical reflection tend to make more structural attributions (e.g., political, cultural, historical, systemic level causes) rather than individual attributions (e.g., personal traits such as intelligence, skills, and effort-based causes) [51]. Previous research has suggested that critical reflection predetermines the critical actions that individuals or collective groups take [14]. For example, urban youth with higher levels of critical reflection have been found to make greater advancements in career development [11]. Such finding suggests the importance of studying teachers' critical reflections, which may provide models for students' critical reflections.

2.3.3 The Role of Cognitive Empathy in Critical Reflection. Currently, the majority of the existing literature on critical consciousness–related constructs, such as critical reflection, has converged on individuals' cognition of and reasoning about social inequities. However, considering that affect and emotion represent the basis of social cognition and consciousness, one cannot discuss the critical consciousness construct without considering the empathetic nature of our human

consciousness. At any given moment, human consciousness works in conjunction with the empathetic consideration of others [9, 48]. Such simultaneous projection or realization of the sensation and feelings between the self and others, also known as intersubjectivity [48], is an indispensable process for activities on the consciousness plane. Therefore, empathy, an integral part of human consciousness, should be considered when discussing critical reflection under the critical consciousness construct in the justice-centered framework.

While there is more than one way to define empathy, the current study defines empathy as "the cognitive awareness of another person's internal states, that is, his thoughts, feelings, perceptions, and intentions" [25, p.29]. Empathy can take different forms across emotional, motivational and cognitive dimensions, such as affective sharing, empathic concern, and perspective taking, respectively [10]. Among others, perspective taking or cognitive empathy, often exemplified as the ability to "consciously put oneself into the mind of another person to understand what she is thinking or feeling" [10, p.3], has been found to strongly predict justice sensitivity and moral motivation [10], which influence individuals' likelihood of recognizing inequitable situations and taking actions to ameliorate injustice. Thus, cognitive empathy may play an important role in the justice-centered framework by influencing critical consciousness and equitable practices. In this study, we examine the role of cognitive empathy, or the understanding of others' unique perspectives and backgrounds, in critical reflection and maintaining equitable learning environments in CS education.

In summary, previous research in science education and computer science education has shown that it is imperative to investigate teachers' understanding of equity issues in CS classrooms through a justice-centered framework [38, 39, 50]. In this study, we address the gap in previous literature by applying the justice-centered framework to interpret high school teachers' conceptualization of equity in CS education.

3 STUDY SETTINGS

In this study, we report on data collected from two cohorts of participants over two years. The participants, who are in-service high school teachers from various disciplines, were enrolled in one of the first CS teacher certificate PD programs in California. Each cohort takes a sequence of four courses to complete the PD program. The participants in cohort 1 joined the program one year prior to cohort 2.

This study consists of two phases: We collected and analyzed cohort 1 teachers' written reflections about equity in CS education in the first year of the program during phase 1, and we interviewed participants from cohort 1 and 2 at the same time in the second year during phase 2.

4 PHASE 1

In phase 1, we examined cohort 1 participants' understanding of equity in CS classrooms and focused on research question 1(a): What are teachers' general understandings of equity issues in CS classrooms after attending a Teaching Exploring Computer Science PD course?

The results from phase 1 were also used to inform the design of the semi-structured interview questions and content analysis in phase 2.

4.1 Phase 1 Participants

The 24 participants are in-service high school teachers from various disciplines in schools that mainly serve underrepresented students. The participants' demographic information is presented in Table 1.

Table 1. Phase 1 Participants' Demographic Information

Categories	n
Ethnicity	
Asian	5
White	14
Hispanic or Latino	4
Other- W Middle Eastern	1
Gender	
Male	16
Female	8
Credentialed Subjects[a]	
Math	14
English & World Languages	4
Science	4
Business	2
Technology[b]	4
Special Education	1
Social Sciences	1
Years In-service	
1–5	3
6–10	6
11–15	7
16–20	5
More than 20	3

[a]Some teachers are credentialed in more than one subject area.
[b]Including Music Technology, Industrial and Technology Education, ICT, Computer Science and Technology.

4.2 Phase 1 Procedures

Cohort 1 participants attended the first course Teaching Exploring Computer Science (TECS) in the two-year program over a duration of nine weeks. The course was offered in a hybrid format, consisting of online asynchronous learning modules in the Canvas learning management system, online synchronous classes on a video conferencing platform, and three monthly six-hour face-to-face classes. The learning experiences in the TECS course were designed to highlight the main thrusts of the ECS curriculum: Inquiry, Equity, and CS concepts. Using PD frameworks suggested in previous research on the ECS curriculum [22], the current study engaged the participants in the Teacher-Learner-Observer model during online and face-to-face classes. The participants also worked on weekly assignments on Canvas, including posting reflection essays based on readings related to equity in CS education (i.e., chapters from *Stuck in the Shallow End*), creating computing artifacts (i.e., webpages created in HTML/CSS, animation/games created in the Scratch environment), and writing lesson plan reflections for adapting the ECS lessons. In the online synchronous classes and the face-to-face classes, the teachers reflected on teaching demonstrations of major ECS lessons that integrate the best practices in promoting inquiry and equity (i.e., using inquiry-based learning to introduce "What is a computer?"; using kinesthetic activities to introduce the concepts of algorithms) and the experiences of creating computing artifacts as learners.

At the end of the TECS course, the participants completed a 500–600-word written reflection on equity issues in CS education. We chose to collect the essay data at the end of the first course because, as indicated in Table 1, the participants were not credentialed in CS prior to the PD program and may have difficulties writing about CS education at the beginning of the course. Details about the written reflection are described below.

4.3 Phase 1 Measures

The participants completed a two-page (500–600 words) written reflection at the end of the TECS course as a take-home project. In two weeks, the participants reflected on equity issues in CS classrooms in general and were allowed to reference any articles they identified as valuable, and/or the reading materials assigned during the course, including *Stuck in the Shallow End* [33] and *Racing to Class* [37].

4.4 Phase 1 Data Analysis

The written reflections were analyzed using the content analysis method [29]. Because the goal of content analysis is exploratory, in which we identified emerging themes in participants' reflections surrounding equity, open coding was conducted in iterative cycles [40]. In the first cycle of coding, two researchers worked independently and assigned preliminary codes to excerpts of text that pertained to equity issues in CS education. After open coding five essays, the two researchers discussed and consolidated preliminary codes. Then one of the two researchers assigned the consolidated codes to the remaining essays and generated new codes in the process when existing codes did not fit with a particular idea unit in the text. In the second cycle of coding, the two researchers read all the selected text under each code and either combined or split the codes into categories or subcategories, respectively [26].

To establish the inter-rater reliability of the codes, another researcher randomly selected 25% of the essays and applied the finalized codes to the text. The inter-rater reliability showed that the researchers reached 97% agreement on the application of codes.

4.5 Phase 1 Results

Findings from phase 1 identified preliminary themes for research question 1(a) What are teachers' general understandings of equity issues in CS classrooms after attending a Teaching Exploring Computer Science PD course? As shown in Table 2, the coding categories generated from content analysis of participants' written reflections include (1) *Students' Roles in Equity*: How students' beliefs and characteristics influence equity in CS education; (2) *Teachers' Roles in Equity*: How teachers' beliefs and practices influence equity in CS education; (3) *The Uniqueness of CS as a Discipline*: How the unique characteristics of CS contribute to inequities in CS education; (4) *Societal Influences on Equity*: How social belief systems and resource allocation impact teachers' equitable practices and students' equitable participation in CS.

Under the *Students' Role in Equity* category, the subcategories focused on the students' *Personal Beliefs/stereotypes about CS* (e.g., female students perceive themselves as not suited for CS classes), the influence of students' *Cultural and Demographic Background* on their development (e.g., low SES students lack prior knowledge), and the *Inequality in Student Participation in CS* (e.g., White males represent the majority of students in CS classes). Among the three subcategories, the teachers discussed the *Inequality in Students' Participation in CS* most frequently (65.38%), suggesting that the teachers in our study consider students' equal access and participation in CS education programs as the most prevalent issues regarding students' roles in equity. These observations point to the weak end of the social justice framework, namely, teachers mainly frame student participation in computer science as the redistributive model of access.

Table 2. Coding Categories of Equity Essay Content Analysis

Categories/Subcategories	Excerpts of Coded Examples	Percent (%)[a]
Students' Roles in Equity		
Personal Beliefs/Stereotypes about CS	"Many of my female and Hispanic students shied away from the topic. Most were indifferent, and many thought that CS was not even on their radar."	23.08
Cultural and Demographic Background	"Not all students come to us with a level playing field. Many students are poor, hungry, mistreated, bullied, etc."	11.54
Inequality in Students' Participation in CS	"For these reasons and others, very few women and minorities are found in computer science classes."	65.38
Teachers' Roles in Equity		
Personal Beliefs/Stereotypes about CS	"We as Computer Science teachers need to overcome negative attitudes about Computer Science . . . that only white collar experts use computers, which is not true."	22.07
Equitable Teaching Practices	"I am becoming more and more mindful of inclusion and have been working on recruiting more female students into my classes."	66.23
Teacher Community	"I will steal as many ideas from other teachers to challenge the high achieving students and to support the low achieving students."	11.69
The Uniqueness of CS as a Discipline		
The Importance of CS	"Computer science is a unique subject that has an opportunity, that not all other subject matters have, to teach students a variety of skills that transfer across all disciplines and prepare students for a complex world."	77.78
CS is Constantly Changing	"These developments make it difficult to stay consistent and "demonstrate mastery" with the information that is being taught."	13.89
CS Content is Challenging	" . . . but a problem lies in the . . . massive amounts of information that are created."	8.33
The Societal Influences on Equity		
Societal Stereotypes and Misconceptions about CS	"Several common misconceptions surrounding the subject that keep many students at a distance."	34.07
Lack of Resources/Curriculum in the System	"It's still amazing to me that in 2017 we don't have any computer science courses in many high schools."	12.09
Lack of Teacher Training in the System	"To make Computer Science a better thing for teacher and students, we need to better educate and train teachers."	15.38
The System Needs to Provide CS Education for All	"Schools and districts need a systematic approach to dispensing computer science curricula to K-12."	27.47
Equity Issues in CS Education Influence the Field of CS	"Computer science will be suffering from the lack of diversity. By limiting the people involved in computer science, the output of these computer scientists will also be limited."	10.99

[a]The percentage for each subcategory is a ratio between the subcategory's code frequency count and the corresponding category's total code frequency count.

The *Teachers' Roles in Equity* category involved three subcategories that essentially described teacher agency in promoting equity in CS classrooms. In the subcategory of *Personal Beliefs/Stereotypes about CS*, the participants discussed the widely held stereotypes among teachers regarding CS education, such as what types of students should attend CS classes. The participants also attributed such stereotypes to the lack of exposures to CS and CS education–related professional development. In addition, the participants pointed out that taking evidence-based PD courses, such as the TECS course as part of the CS teacher authorization program, can help to change stereotypes and help educators to see that CS is for all students. The teachers also discussed implementing *Equitable Teaching Practices* (e.g., recruiting diverse students into CS classes); and *Teacher Community*, where references were made to the importance of learning from and contributing to teacher communities regarding equitable practices (e.g., the need to learn from other teachers to promote equity in CS classes, and communicate with other teachers to change their stereotypes about CS). As shown in Table 2, under the *Teachers' Roles in Equity* category, *Equitable*

Teaching Practices was discussed most frequently, suggesting that most of the participants recognized the importance of implementing equitable teaching practices in their classrooms. With regards to teachers' critical reflection, these findings suggest that the participants took note of the environmental factors essential to equity (i.e., exposure to equity-oriented professional development, teacher community). However, these factors still center on the redistributive model and emphasize equal distribution of resources such as PD programs and supporting resources.

The category of the *Uniqueness of CS as a Discipline* focused on the factors that make CS an important yet challenging discipline. Among the three subcategories, most of the discussions focused on *The Importance of CS* (77.78%), where the participants recognized that CS teaches important and fundamental skills, such as critical thinking and computational thinking. In addition, the participants also reasoned that the constantly changing and the innately complex subject content in CS has created challenges to both teaching and learning, and may have contributed to inequities in CS education. These findings suggest while teachers recognize the importance of CS and its promising benefits—preparing students with skills fundamental to all disciplines—they are also aware of the potential challenges it creates to maintaining equitable learning environments.

The *Societal Influences on Equity* category focused on societal factors, including the beliefs and practices in the society that contribute to pervasive equity issues in CS education. The subcategories involved *Societal Stereotypes and Misconceptions about CS* (e.g., the society tends to perceive women as less suitable for CS than men), the *Lack of Resources/Curriculum in the System* (e.g., many schools do not offer CS classes), the *Lack of Teacher Training in the System* (e.g., there are very few CS PD programs available), and *The System Needs to Provide CS Education for All* (e.g., schools and districts need to have a system in place to provide CS education for all students in k–12). Among the five subcategories, most of the discussions focused on *Societal Stereotypes and Misconceptions about CS* (34.07%), such as how the society tends to perceive certain groups as more suitable for CS (e.g., men are more suitable for CS than women). Notably, in the subcategory of *Equity issues in CS Education Influence the field of CS*, the participants described the mutual influence between students' participation in CS and the equity issues pervading the CS discipline/industry. For example, the participants suggested that inequities in the CS workforce can reinforce stereotypes about who can become a "CS person" and prevent students, especially female and underrepresented students, from participating in CS. In addition, the participants observed that the CS discipline and society would in turn suffer from unequal participation and the lack of diversity in CS education, because under-utilizing the potential contributions by females and underrepresented groups would inevitably slow down the advancement of the field. These findings suggest that the participants became aware of the impact of societal beliefs in the students' social environment on their equitable participation in CS education. While these discussions highlight the issues embedded in the social system, they mainly focus on the redistributive model of providing resources/curriculum and making changes to individuals.

5 PHASE 2

In phase 2, we examined the participants' responses to the semi-structured interviews and explored research questions 1(b), 2, and 3. The semi-structured interview allowed for an in-depth exploration of teachers' understanding by situating the equity issues in the context of their school and classroom environment.

In this phase, we chose to aggregate findings from the two cohorts and discuss them as a whole. This is because through the lens of the justice-centered framework, both cohorts' perceptions of equity showed similar patterns and areas for improvement. In addition, the aggregated findings may provide guidance for future PD programs regarding what needs to be done and areas worthy

Table 3. Phase 2 Participants' Demographic Information

Categories	n
Ethnicity	
Asian	1
Hispanic or Latino	4
Multi-ethnic	1
White	6
Gender	
Female	6
Male	6
Credentialed Subjects[a]	
English & World Languages	3
Math	3
Technology [b]	2
Science	2
Social Sciences	1
Special Education	1
Visual Performing Arts	1
Years In-service	
1–5	1
6–10	3
11–15	4
16–20	2
More than 20	2

[a]Some teachers are credentialed in more than one subject area.
[b]Including Music Technology, Industrial and Technology Education, ICT, Computer Science and Technology.

of explicit instruction to facilitate teachers' perceptions of equity based on the justice-centered framework.

5.1 Phase 2 Participants

In the second year of the PD program, we randomly selected 12 teachers using stratified sampling. The participants were stratified into subgroups based on cohort and gender. In each cohort, six participants were selected to receive the semi-structured interview. Table 3 presents the demographics of participants. On average, the teacher participants' schools have 36.1% under-represented students, and 36.62% students are in need of free and reduced lunch.

5.2 Phase 2 Measures

The teachers were interviewed using a semi-structured interview protocol, in which they were prompted to discuss equity issues in the context of their schools and classrooms. The semi-structured interview protocol was derived from the major themes identified in the content analysis of the written reflections from phase 1 of the study. Hence, the interview mainly tapped into teachers' roles in equity, students' roles in equity, CS as a unique discipline, and the social dimension of equity in CS education.

To design the semi-structured interview guide, we referred to the recommended procedures in Kallio's [27] work. We first obtained expert opinions and existing literature in the field of CS education and equity research. Then, we drafted questions that are participant-oriented, clearly worded, and open-ended [27]. The wording and sequence of the questions are also specifically designed to help situate the participants in their authentic school and classroom context. For example, the interviewers obtained information about the participants' classroom context through the initial questions and posed subsequent questions based on this context (e.g., start with "In general, can you briefly describe the learning of the students in your class," followed by "What do you know about the backgrounds of the students in your class?").

To test and refine the questions, we conducted trial sessions with graduate students who had experience teaching in high schools. Based on their feedback, we revised the questions in the interview protocol to clarify meanings and to ensure that there were no leading questions.

5.3 Phase 2 Procedures

5.3.1 PD Courses. Phase 2 of the study took place when cohort 2 participants were taking their first class—TECS, which is the same as the one described previously in phase 1.

Concurrently, cohort 1 participants were taking the third class—the Methods of Teaching Computer Science. Prior to this, they first participated in the TECS described in phase 1, then took the second class—Teaching Computer Science Principles (TCSP), which lasted for five weeks and used a hybrid format similar to TECS.

In TCSP, the cohort 1 participants had access to online asynchronous learning modules in the Canvas and EdxEdge learning management systems, online synchronous classes on a video conferencing platform, and five weekly three-hour face-to-face classes. The learning experiences in the TCSP course were designed to highlight CS content related to programming and applying teaching strategies that promote equity in classrooms. The participants learned about using object-oriented programming to solve problems in the Alice environment by completing online learning modules in the Canvas and EdxEdge learning management systems, and discussed applying equitable teaching strategies such as peer-instruction in both face-to-face classes and synchronous online classes via video conferencing platforms.

Similarly, the MTCS was also delivered in a hybrid format, with online asynchronous learning modules on the Canvas learning management systems, online synchronous classes on a video conferencing platform, and two monthly three-hour face-to-face classes. The purpose of the methods course was to help the participants gain an in-depth understanding of the pedagogical knowledge related to teaching computer science and learn about the current research on CS education. In the asynchronous online learning modules on Canvas, the participants read research papers on issues related to equity, problem-solving, computational thinking, and composed written responses in the discussion board according to selected reading prompts. The participants were also encouraged to respond to others' posts on the discussion board. During synchronous online learning, the participants discussed their reflections on the reading materials, refined lesson plans for the ECS or CSP classes, and discussed pedagogical strategies to facilitate the learning of challenging topics across the two curricula.

The semi-structured interviews for both cohorts took place around the same time: during the final weeks of cohort 2 participants' first class, TECS; and cohort 1 participants' third class, MTCS.

5.3.2 Equity-focused Activities. All the PD courses consist of several types of activities that aimed at promoting the teachers' perceptions of equity. For example:

- Reading materials on equity in CS education (e.g., *Stuck in the Shallow End*) were assigned and teachers responded to reading prompts in online discussion boards to reflect on racial

disparity, gender bias, growth mindset, broadening participation, and social/cultural context.
- Teachers applied CS concepts and equity practices to design lesson plans in groups. Using the Teacher-Learner-Observer model, they also engaged in micro-teaching and peer-reviewed the lesson plans to learn from shared experiences on delivering CS concepts in equitable ways.
- PLC meetings were held monthly to strengthen teacher collaboration and establish a strong teacher community to discuss and mitigate the inequity issues. For example, many teachers shared resources that may support equitable practices and broaden participation, such as ways to work with school counselors to enroll underrepresented students in CS classes, recent CS conference and competitions, or internship and research opportunities for students.

5.4 Phase 2 Data Collection

The semi-structured interviews were conducted with the participants either in their schools or at the face-to-face classes based on their schedules. Each interview took about 40 minutes on average.

The three interviewers are researchers in CS education with experiences in qualitative research and interviewing. In addition, prior to conducting the interviews, one of the three interviewers served as the observer while the other two rehearsed the interview protocol in pairs. Then the three interviewers debriefed on the interview process and compared against standards introduced in previous research regarding interview techniques [32]. During the rehearsal, potential follow-up questions were also added to the interview protocol. Due to the nature of the semi-structured interviews, the three interviewers were allowed to ask more follow-up questions to encourage the participants to elaborate on certain concepts or ideas that the participants mentioned.

5.5 Phase 2 Data Analysis

Audio recordings of the interviews were transcribed verbatim in preparation for qualitative content analysis [26]. Due to the length of the interview transcripts, the content analysis employed a collaborative coding process involving three researchers [6] and was done in the MAXQDA software, which supports collaborative coding [47].

In the first round of coding, the three researchers started with developing an initial coding scheme based on the results from the content analysis of the equity reflection essays in phase 1 of the study, including the overarching categories in *teachers' roles in equity, students' roles in equity, the uniqueness of CS as a discipline, and the social dimension of equity in CS education.* Then the researchers used the content analysis method [26] to analyze the same two randomly selected interview transcripts independently. Based on the content analysis results, the researchers discussed the codes together and created top-level categories and sub-level codes to constitute a code book.

In the second round of coding, the three researchers first recoded the same two transcripts to train themselves on using the code book and to check for inter-rater reliability. When the inter-rater reliability reached 91%, the researchers started to code different transcripts independently until all of the transcripts were coded. In this process, the researchers generated new codes if none of the codes in the code book were applicable. After the independent coding, the three researchers met to discuss the coding results. Using the multi-user code system management in the MAXQDA software, the researchers consolidated duplicate new codes and integrated the new codes into the existing coding system. The major categories are presented in Table 4.

To check the fidelity of the code application, one researcher randomly selected and recoded 1/4 of the transcripts done by the other two researchers and the inter-rater agreement reached 93%. The researchers also discussed to resolve the discrepancies among the application of the codes.

Table 4. Coding Categories of the Interview Content Analysis

Categories/subcategories	Codes
Equity in CS Education	
Equal access	
	Equal participation in CS courses
	Equal access to CS resources
Political nature of CS education	
	Distribution of funding for CS resources
	Influence on students' career pathways
	The right to access CS knowledge
The role of empathy	
	To understand the students' unique challenges
	To learn about students' backgrounds
	Relating to the students' emotional/life experiences
Teachers' Roles in Equity	
Equitable teaching strategies	
	Providing equal access to CS resources
	Considering students' backgrounds
	Building rapport
	Enhancing motivation
	Using pedagogical approaches
	Addressing maladaptive issues
Attribution of inequities	
	Students' affective and motivational barriers
	Lack of background knowledge
	Lack of access to resources
Social Support	
	Funding CS resources
	Professional development opportunities
	Support from the professional community

Note: This table is organized according to the coding scheme used in the content analysis. In the results section, the codes and excerpts are organized according to the research questions.

5.6 Phase 2 Results

5.6.1 Teacher Understandings of Equity in CS Education. To probe research question 1(b) on how teachers perceive equity issues in CS classrooms in the context of their school environment, we examined the content analysis of participants' responses to the semi-structured interviews and identified themes relating to the dimensions of *Teacher definitions of equity in the context of CS classrooms*, *the political nature of CS education in the context of equity*, and *the role of empathy in equity.*

5.6.2 Teacher Definitions of Equity in the Context of CS Classrooms. The content analysis results showed that the participants' definitions of equity converged on two themes: *equal participation in CS courses* and *equal access to CS resources.* Throughout these themes, equity was portrayed as equality, that is, as equal participation and equal access to resources. This points to an understanding of equity that is limited to how resources and opportunities are distributed among students. There is little discussion of how student participation is influenced by systemic factors that may perpetuate inequitable participation and may represent the root causes of unequal access.

Equal participation in CS courses. Participants described that they define equity in CS classroom as enrolling more under-represented students, such as female students.

> "There are fewer girls in computer science than boys and I think it should not be the case."

> "I would say an equitable class would have definitely more female representation."

Equal access to CS resources. All participants described equal access to resources as a defining component of equity. The participants stated that regardless of the students' backgrounds and socioeconomic status, they should have access to computing resources, such as computers, the internet, and curriculum:

> "I would say equity is the students actually having their tech computer resources."

> "As far as equity is concerned . . . I would define it as, um, having access or things being pretty equal across the board."

> "My definition of that [equity in CS education] would be . . . class is offered to everybody who would like to experience it."

In essence, the participants seemed to regard equity as an embodiment of equality:

> "It [equity] seems very similar to like . . . equal or equality to me, just kind of like access [to resources]."

In addition, while "resources" can mean a variety of things in the context of CS education, the participants focused more on the tangible computing resources, such as Chromebooks, laptops, and the internet:

> " In terms of technology like everyone has equal access to the technology and that on campus we have computers all around campus and Wi-Fi for them."

The participants explained that having access to such computing hardware is the key to realizing equity in CS education, because students would not be able to work on computing projects without them:

> "I wouldn't have them, say, okay, 'I'm going to tell you this now, go home and do it.' . . . not everyone's going to have access to it.

This emphasis on tangible resources suggests that the participants mainly view equity in CS education as students having equal learning opportunities given equal access to computing resources. However, increasing participation and equal access to resources involves making changes at the individual level and avoids dealing directly with valuing students' culture and exploring structural issues [8].

5.6.3 The Political Nature of CS Education in the Context of Equity. Most of the participants (10 out of 12), when asked about their views on the political nature of CS education, responded that they could not see how CS education can be political:

> "I don't see it that way. I just see it as strictly education."

> "I don't understand why it would be political in nature. I mean, I think in the sense that you need to have a computer . . . , but there are so many free resources out there . . . Right? So as long as you have access to a computer and Wi-Fi, I guess that would be critical."

After the interviewers probed further by explaining that the political dimensions can be viewed from the social power aspects, some participants described that the political dimensions may be reflected as:

The right to access CS knowledge, such as taking computer science as required courses to develop their computational thinking skills:

> "If they don't like computer science, they don't have to do it, but it's information that they should have access to so they can decide what they want to do . . . "

> "Like even today, we build a website, right? We're doing design. There's design on that. So there's geometry, there's math, there's coding, there's understanding order of operations . . . . I don't feel like this should be an elective course for them. I feel like every single kid needs to understand a little bit of the back end of what's happening. Like, it's not OK for them to just know how to use an app."

For teachers (2 out of 12) who acknowledged the political nature of CS education, they mainly focused on the dimensions of **distribution of funding for CS resources** and **career pathways**.

Distribution of funding for CS resources. The participants pointed out that political institutions can determine the availability and distribution of funding for CS, which is dependent on how well the institutions recognize the importance of this discipline:

> "What I feel is that the people making decisions don't know anything about it (CS) . . . So it is political but it's not being addressed."

> "And I totally believe that at this moment they're . . . they're not putting in what our taxpayers put in to give our students an equitable education [in CS]."

Influence on students' career pathways. The participants also suggested that CS could be a mechanism for social power as the job market becomes more digital and tech-based. Having CS knowledge leads to more professional and utilization opportunities, which contribute to the students' career trajectories:

> "I definitely believe it is political in nature . . . . Um, students have been getting more and more denied from colleges and I think if they have computer science and other things like that, then the colleges would look at them and their resume would go higher."

> "I strongly encourage everyone [to learn CS] because of the market, because I feel like education and the job market has big gaps . . . . So, if we think about artificial intelligence . . . everyone should be learning [CS] because artificial intelligence is gonna eliminate a lot of jobs. So, we have to be prepared, we have to teach students [CS] to be prepared . . . [for] this job market."

Therefore, although previous research has emphasized the political nature of education [8, 39], the interview responses suggested that most of the participants found the political nature of CS education in the context of equity to be a rather unfamiliar and obscure concept. This points to the need for more explicit and focused professional development experiences that help teachers understand how social, political, and economic forces converge to create inequitable conditions for underrepresented students.

5.6.4 The Role of Empathy in Equity. In general, all the participants recognized the connection between empathy and equity.

> "I think there's a very strong relationship between equity and empathy."
>
> "As an instructor, it is important to try to be empathetic so you can provide the equity."

In discussing the role of empathy in equity, the participants identified three major themes:

To understand the students' unique challenges. The participants indicated that empathy allows them to understand the challenging situations facing students who lack access to CS resources and provide accommodations.

> "I think it [empathy and equity] goes hand-in-hand when you realize that . . . when someone doesn't have the [resources] . . . there's no access to something, then you need to understand that and then figure out a way to make it more equitable so that they can [have access] . . . . So, I think the empathy comes in understanding [that] . . . I need to provide a pathway or a way for these students to access the information so they can be successful."
>
> "So, being empathetic or being understanding about other people's situation. I think that tends to be something that a lot of people don't understand because they come from wealth, they come from access, they come from privilege . . . . So, I think that's an area [empathy] that really could be, you know, [be] introduced a little bit more."

To learn about students' backgrounds. According to the participants, being empathetic about students' unique backgrounds can convey to the students that the teachers care about them, a crucial element in creating equitable learning environments in CS classes:

> "Empathy towards equity is necessary for a class to be equitable . . . to understand the relationship, the cultural background, the cultural history they bring to this class."
>
> "Empathy makes it more equitable. Definitely . . . because I feel if you're empathetic to students, they will feel that you care about them, that you care about their interests, you care about how well they're doing and then that will make them feel more likely to pursue it and to feel that they can do it."

This points to a strong understanding of how empathy relates to the social justice framework by taking into account the cultural and historical factors that characterize students' backgrounds and how those characteristics can be leveraged to promote equity.

Relating to the students' emotional/life experiences. The participants explained that perspective-taking, which is part of cognitive empathy, can help them understand and relate to the challenges in students' emotional and life experiences.

> "So that your first reaction is not that the boy is mad with you or whatever, but maybe that's how he's expressing himself. Or maybe that's how he wants and needs attention or maybe this week there's something going on with him outside of school. So, the day students become numbers, that is the day you quit teaching. So, you really have to . . . trying to understand what the students are going through . . . "

Such views align with the importance of cognitive empathy—the perspective taking of another person's thought processes, feelings, and experiences [10]. While the cognitive empathetic understanding of the "mind of another" should be the basis of all teaching endeavors, it may be particularly crucial to creating equitable environments in CS classes.

5.6.5 Strategies for Addressing Equity Issues in CS Classrooms. In regards to research question 2—the strategies that teachers use to address the equity issues in high school CS classrooms, the participants described equitable practices that focus on **teaching strategies** and **social support**.

For example, the participants identified the following equitable teaching strategies:

Providing equal access to CS resources, such as providing computers for the students:

> "I tried to do things where they could come early in the morning, come during their lunch, use a computer in the library so that they didn't fall behind and work on what was being done."

Considering students' backgrounds. The participants acknowledged the importance of learning about students' backgrounds. However, despite the fact that backgrounds can include culture/knowledge/family and communities, when discussing equitable teaching strategies, the participants showed the trend of focusing on the dimension of prior knowledge. They mainly stressed the importance of helping students with different levels of prior knowledge to succeed by modifying curriculum and materials:

> "I take into consideration the student's level. Um, I also take into consideration what their background knowledge is of the subject."

> "I don't want anyone to think that they can't do the work . . . and that we all come at a different level when they enter the classroom. But by the time we finish we should all have an understanding of all the different concepts."

> "You modify as needed for your low- and your high- [skill-level student] but I guess to ensure that everything was equal I would probably end up teaching to my lowest common denominator and then I would do expansion activities for my really smart kids. That's kind of how I would make it equitable."

The participants also indicated the necessity to consider students' backgrounds in learning styles and employ various modes of teaching:

> "You've got to give it to them in every way, written, speaking, and writing, acting, drawing, coloring, images, video. I mean, they've got to see it in multiple formats. You've got to experience the content in multiple formats; that's how you create equity."

Building rapport. The participants emphasized building rapport with students to create a sense of belonging, for example:

> "Um, so first of all, uh, at the beginning of all of my classes, I try to develop a sense of community and make it like a little mini family type of thing. So, um, I think once you build that rapport and that trust with each other, it's a lot easier to help one another . . . ."

Enhancing motivation. The participants enhance the motivation of low-achieving students, female students, and students from relatively low socioeconomic status families by promoting their interest:

> "I can try to get them interested in learning. Again, the motivation. Right. It's mainly trying to get them excited about learning."

Or creating a safe learning environment for making mistakes, because making mistakes is part of the learning process, especially in CS:

> "They are afraid of being ridiculed by the other students or they're afraid of what other students might think of it. Because, uh, that's one thing they have to learn in my class is we have to be able to trust each other and that's why actually they get points if they are wrong [making mistakes in activities]."

Using pedagogical approaches. The participants described the necessity to use specific pedagogical approaches, such as collaborative learning and fostering growth-mindset, to enhance equity. Almost all the participants mentioned collaborative learning as a major strategy for creating equitable CS learning environments.

Pair programming. While there is a variety of collaborative learning models, the teachers cited pair programming as a strategy that they would continuously apply in their CS classrooms:

> "In CS, the pair programming and collaborative nature lends itself well to creating equitable environment."

Peer tutoring. The participants also highlighted using peer tutoring, peer instruction, and peer evaluation, where students of different levels can work together and help each other in problem-solving:

> "But peer tutoring, peer evaluations, peer instruction has been a big part in bringing them out of the struggle."

> "Maybe give a half hour . . . and students can work together on helping each other to . . . understand how to do the programming."

Fostering growth-mindset. Furthermore, the participants described the benefits of fostering growth-mindset as a pedagogical approach: Everyone has the potential to learn CS regardless of their prior knowledge and experience:

> "I started telling my students who were struggling . . . . 'So don't give up. We can still do this. If you don't get it now, that's okay. We can keep working on it. And so at the end you should be able to do it."'

Besides the aforementioned strategies that focus on equitable teaching strategies, the participants also identified other strategies that rely on **social support**:

Funding CS resources. The participants emphasized the importance of support from the school and district level that may provide:

> " . . . the funds for these different computing resources . . . "

Professional development opportunities. In addition, many teachers highlighted the indispensable role of professional development for addressing equity issues in CS classrooms:

> " . . . for me not having a computer science background, I think that the training is super helpful."

Support from the professional community. The participants also stressed professional community support in promoting equity in CS education. They expected to enroll more students with the help of school counselors to improve curriculum through working closely with experienced CS teachers and to develop relationships with colleges and universities to create more internships and job pathways for their students.

Addressing maladaptive issues. It is also important to note that the teachers discussed a few maladaptive strategies that may prevent educators from establishing equitable learning environments. For example, the participants mentioned that despite the importance of understanding

students' backgrounds in fostering equity in CS classrooms, information about students' cultural backgrounds are difficult to obtain and most of the student information the participants had access to were demographic numbers, such as the percentage breakdown of gender and ethnicity:

> "It is difficult to know about home life .... What we are given is numbers and info about demographics, test scores."

Consistent with these statements, all (12 out of 12) participants used demographic numbers to respond to questions regarding what they know about students' backgrounds:

> "The majority of my students were ... I had 60 percent boys and 40 percent of girls which I thought was very good."

Most importantly, when asked about their understanding of students' cultural backgrounds, the participants pointed out that they found getting to know the students' unique cultural/familial backgrounds to be a challenging process and are in need of additional support from school administrations and PD programs to provide guidance.

> "Getting to know students is how you learn about other aspects, things that might present struggles .... Difficult to get past hurdle if students don't open up at the front end of that conversation. What is life like for you? Some classes can't get kids to open up. If you can't get kids to open up, you can't learn about what is going on in their life."

> "...but it's hard for me to relate, because I don't have those [same] cultural backgrounds...it's easier for me to relate to the [name of the specific ethnic group omitted] students than the other students. But, um, it's hard."

5.6.6 Teacher Attributions of Inequities in CS Classrooms. Results regarding research question 3 showed that the participants primarily attributed the inequities in student performance to myriad individual causes, as opposed to structural causes, including *students' affective and motivational barriers, the lack of background knowledge,* and *the lack of access to resources.* This points to a limited understanding of how socially unjust practices are perpetuated at the social, historical, and cultural levels for underserved students.

Students' affective and motivational barriers. The participants attributed inequities to the students' lack of motivation, confidence, persistence, tenacity, or effort:

> "And then for the struggling students they tend to be like, 'I can't even [succeed] in these types of experiences.'"

> "I've got a couple of girls that aren't particularly interested in the course. And so they don't really work very diligently towards it. I've noticed that, you know, they don't want to move on...and they're sort of not engaged in it...they do want to get a good grade, but they don't really want to learn computer programming."

Students' lack of background knowledge. The participants cited the limited prior knowledge in reading, writing, math performance, and the lack of analytical and critical thinking skills as the individual causes of persistent achievement gaps:

> "I think students from low SES backgrounds have gaps in reading and writing levels, that then shows itself in achievement scores and the present computer science achievement gap."

The lack of access to resources. The participants referred to the limited access to technology among students from low SES backgrounds, such as lacking computers and the internet at home, as the individual cause of the inequities in CS learning.

> "Those are the struggling ones who didn't have computer or Internet access at home. They may have had a computer but they don't have internet . . . they'd have to bring their laptop to a Wi-Fi [portal] in order to send something. [This is difficult when] all of Code.org is all online."

> "I think the students [who] have no access to technology [are at] a huge disadvantage. Like, they didn't really have computers or the internet at home and they don't have it exposed in some other environment. So they come into it and they're like, OK, but they don't know how . . . HDMI works or USB works."

6 DISCUSSION

Overall, the findings from this research corroborate previous literature by showing that the participants mainly defined equity as providing equal participation and equal access to computing education opportunities. This result aligns with the previous research that highlighted the urgency of broadening participation by providing equal access to CS education [35]. The findings also suggest that there is a strong need to facilitate teacher discourse around equity to extend beyond equal access [8, 39].

6.1 Teacher Understanding of Equity Issues in CS Classrooms

6.1.1 Teacher Definition of Equity. Findings from this study suggest that participants tend to conceptualize equity in CS classrooms as promoting the participation of underrepresented groups and providing equal access to resources. However, focusing on enrollment data and education infrastructures shies away from the complex social-cultural dimensions that underlie the equity issues in CS education [8, 36, 39]. The findings also add to previous research by showing that, among other underrepresented groups and resources relevant to CS education, high school CS teachers tend to consider recruiting more female students and providing tangible resources (i.e., laptops, internet) as central to addressing equity issues.

The finding that the teachers gave prominence to equal participation and access in their definition of equity is consistent with the previous research in CS education as well as other science education disciplines, where much of the discussions on equity have been found to fixate on access [7, 36]. As recent research has suggested, inclusive and equitable learning environments should involve both redistributive and relational models of social justice, ranging on a spectrum of weak to strong socially just practices [8]. Almost all of the participants in this study defined equity in the CS classroom as making sure that the students have equal access to materials and resources, which is more akin to the notion of equality emphasized in the redistributive model and lies on the weaker end of the spectrum of socially just practices [8]. Therefore, the findings from this study suggest that PD programs should help CS teachers develop comprehensive understandings of equity, one that not only considers the redistributive model but also values students' culture and differences to facilitate strong inclusion practices highlighted in the relational model [8].

A potential rationale for the teachers to define equity as providing equal access to CS curriculum and resources may have stemmed from the widely held conception about access—that is, "having access" is always a good thing [8, 31]. Such a notion may have been further strengthened by the widely documented lack of access among underrepresented groups in CS education [2, 33]. However, recent research has cautioned against equating access to equity or viewing access as automatically a good thing: Without considering the differences in culture and individual needs,

providing access risks advocating the values and voices of the groups in power [8, 24, 31]. In addition, focusing on access may decontextualize students from the systems in which they are embedded and may shift the focal point of addressing equity issues from changing the system to making changes to the individuals [7, 8]. Thus, future research should identify ways to help teachers recognize that focusing on equal access circumvents the other equally if not more important aspects of equity, such as valuing the students' socio-cultural background and specific needs [8]. The justice-centered framework discussed in this study may serve as a viable means to help teachers go beyond the focus on access and re-examine the fundamental dimensions of equity in CS education.

6.1.2 The Political Nature of CS Education in the Context of Equity. The findings from this research showed that teacher participants acknowledged the role of CS as an important determinant of social power in this era: CS knowledge and skills lead to gains in professional opportunities and social capital. This realization is consistent with the uniqueness of CS as a discipline identified in previous research [20, 23]. However, the findings also suggested that most teachers found it challenging to interpret the political nature of CS education. For the few participants who acknowledged the political dimensions, they mainly focused on how social institutions provide funding and resources. This finding provides a contrast to the long-standing notion in the critical theory literature that teaching is political in nature [39] and beyond issues related to access [8, 30, 50, 51].

Moreover, previous research has emphasized that teachers should become critically aware of the political dimension of teaching so they can identify the power hierarchies in the discipline and acknowledge students' rich social and cultural values oppressed by the groups in power [7, 39]. Such awareness would also allow teachers to create authentic learning experiences that are personally meaningful to the students, whose rich backgrounds are embedded in the diverse political, social, cultural, and economical context. Therefore, this finding also adds to previous CS education research by showing that teachers may have difficulties identifying the political attributes of CS education as well as recognizing their roles in creating equitable CS learning environments given the political dimensions of this discipline. Such finding suggests the need to structure PD activities that engage teachers to identify the political dimensions of CS education and their roles in empowering students to be the agents of change.

6.1.3 The Role of Empathy in Equity. The findings suggest that the teachers perceived empathy as having important roles in promoting equity. All the participants acknowledged that empathy is closely related to equity and serves as a prerequisite to fostering equity in CS classrooms. The participants reasoned that empathy is essential to understanding students' backgrounds and recognizing students' challenges, such as lacking access to resources. These elements are fundamental to critical reflection, the process of analyzing the causes of persistent inequities among different groups [12, 18, 51]. This finding is consistent with previous research that highlighted the important role of cognitive empathy, or perspective taking, in predicting justice sensitivity and moral motivation [10, 25], which contribute to recognizing inequities among social groups and taking action to ameliorate injustice. Therefore, these findings build on the critical consciousness literature by showing that from the teachers' perspective, they consider cognitive empathy, or the ability to take the perspective of the students, as an important component in critical reflection.

Based on the teachers' reflections and the previous research, the empathy component may add to the critical reflection construct in two ways. First, cognitive empathy allows teachers to understand and value students' unique perspectives, which may help teachers to view such uniqueness as students' funds of knowledge stemming from diverse cultural experiences rather than as the signs of "lacking." (E.g., "The students have demonstrated this unique perspective because they experienced XYZ in their culture/home environment; and we can provide appropriate support to

build on their unique funds of knowledge," rather than "The students lack the required skills to perform at this level because they don't have XYZ in the home environment.") Accordingly, teachers may also be less likely to attribute the inequities in CS education to individual-level factors, such as students' "lacking" in backgrounds, while acknowledging that these differences in backgrounds underscore students' unique needs and funds of knowledge.

Second, cognitive empathy can help teachers see that many of students' individual characteristics, such as "thoughts, feelings, perceptions and intentions" [25, p.29] are dynamic internal processes rather than fixated personal traits. This recognition can be especially helpful for critical reflection, because it would allow teachers to understand that the students' internal processes are constantly changing and interact dynamically with their unique environments and communities. With such awareness, the teachers may be less prone to attribute inequities to these individual characteristics or internal processes during critical reflection.

Thus, for teachers to effectively enact equitable practices, cognitive empathy may be a necessary component in the critical reflection process. Future studies should investigate strategies that promote cognitive empathy and explore how cognitive empathy may influence critical reflection.

6.2 Strategies for Addressing Equity Issues in CS Classrooms

The findings suggest that the participants valued the practice of understanding students' backgrounds and advocated using a series of equitable practices, such as motivating students, creating safe environments for making mistakes, using inquiry-based learning and collaborative learning to create equitable learning environments. Such findings are consistent with previous research that emphasized using equitable teaching strategies in CS classrooms to build on students' prior knowledge and promote meaningful learning [22].

This study also adds to previous research by demonstrating that in regards to considering students' backgrounds, the teachers mainly focused on prior knowledge/skills and made little reference to social-cultural backgrounds. This provides a contrast to the important role of social and cultural context in equitable teaching practices identified in previous research [7, 31]. As discussed previously, teachers' in-depth understanding of social-cultural background is crucial to helping students make personally meaningful connections with CS knowledge and take what they learn to empower communities in culturally relevant ways [8, 21]. In addition, teachers' recognition of students' social-cultural resources can help counter deficit-based views and convey the idea of CS for all where all students can succeed in CS given sufficient culturally relevant support [13, 43, 45]. Thus, future study should explore ways to help teachers recognize the indispensable role of students' social and cultural backgrounds and consider these backgrounds while creating equitable learning environments [41].

A potential explanation for the participants' limited reference to students' social-cultural backgrounds is that they lacked an effective channel for getting such information. For instance, as documented in the findings, some teachers expressed having difficulties finding out about and understanding students' cultural backgrounds. Besides, the types of student information that school administrations normally provide for teachers may have unintentionally encouraged teachers to attend to certain types of background information. For instance, the findings showed that the participants mainly had access to demographic reports on ethnicity, gender, socioeconomic status, and language performance. And during the interview, when asked about students' cultural backgrounds, some participants responded only with demographic statistics, including gender breakdowns and percentages of different ethnic groups. To address these issues, it is advisable that stakeholders such as school administrators emphasize social/cultural backgrounds as much as demographic statistics. After all, the numbers and percentages can only offer a limited portrayal of students' backgrounds.

Additionally, future CS teacher PD programs can consider providing teachers with strategies to learn about students' cultural backgrounds, such as structuring learning activities to promote the sharing of cultural and participatory roles relating to students' unique backgrounds. Pioneering work in youth participatory research has shed light on the possibilities of encouraging communications about students' cultural backgrounds in formal or informal learning environments [11]. The collaborative learning approaches in the form of peer instruction or peer programming, mentioned by several teachers, also provides the potential to engage students in activities that make use of their funds of knowledge and cultural wealth.

Other strategies, such as Culturally Responsive Teaching (CRT), can also help to engage culturally and linguistically diverse youth by viewing students' heritages as assets to be leveraged for learning. Previous research has shown that culturally responsive practices can sustain motivation for diverse learners [43] and promote learner agency for underserved youth [45]. For instance, Scott, Sheridan, and Clark [42] discussed the integration of issues of diversity, community, culture, and identity into technology programs to provide culturally relevant computing experiences for diverse sociocultural groups. During CRT, teachers reflect on their own cultural competence to better understand how their worldviews and privileges influence the learning environment [49]. This type of reflection echoes the social justice framework's notion of critical reflection in recognizing the power dynamics and structural causes that perpetuate inequities for underserved groups. During critical reflection, teachers begin to develop an understanding of how they can position themselves within learning communities to build equitable opportunities for students that leverage their socioculutral resources.

6.3 Attributions of Inequities in CS Classrooms

This study builds on previous research by demonstrating that, based on the justice-centered framework, the teacher participants' critical reflections mainly focused on the individual, rather than the structural causes of inequities [51]. For example, the participants attributed inequities and achievement gaps to a series of individual-level factors, including personal characters (e.g., motivation, effort, persistence, tenacity); backgrounds (e.g., knowledge and skills, family situations); or access to resources (e.g., laptops and the internet). Few attributions were made to structural causes, such as societal structures and policies as well as social, cultural, and historical backgrounds.

These findings corroborate previous research that showed the prevalent individual-level attributions among educators [8, 38]. However, while individual-level factors constitute part of the barriers to equity in CS education, issues at the structural level are the root causes of inequities that reproduce and perpetuate performance gaps [38, 39]. Besides, emphasizing individual causes over structural causes could engender unintended repercussions: It may provide grounds for problematizing underachieving students' situations as deficits to be "fixed" or made "sufficient"; it may strengthen the deficit-based view that does not value the wealth of students' cultural and linguistic resources [17] and may prevent one to see and build on what students already have [36]. Thus, making individual-level attributions to the "lack" in backgrounds and skills can further exacerbate the suppressed status of underserved students [17, 46].

In contrast, acknowledging structural causes would allow teachers to devise learning activities that empower students to be the agents of change in their communities and traditionally suppressed groups [38]. For example, studies in youth participatory research have reported having students create computing artifacts (e.g., games) or organize community events (e.g., gallery walks) to raise the awareness of disadvantaged communities that computer science is for all [36]. The development of such empowering activities relies on the premise that teachers are cognizant of the structural causes of inequities for suppressed individuals and groups.

It is also important to note that reading materials on CS education equity, which have widely documented the lack of access to resources among underrepresented groups [2, 34, 44], may influence teachers' perceptions about structural and individual-level issues. Admittedly, it is possible that previous research has presented individual-level issues such as access to illustrate the implicit and underlying structural issues. However, without making explicit references to structural issues, the reading materials may have unintentionally led teachers to lean towards individual-level attributions for inequities in CS education. Thus, future research should explore how to facilitate CS teachers' critical reflection and help them recognize structural causes of inequities [2, 7, 21, 33, 35].

6.4 Limitations

This study has sampling limitations that are inherent in qualitative type of studies. The findings from this study are in-depth explorations of the research questions based on available cases and may not be generalizable to other types of populations, where generalizability is often not the main goal of qualitative studies. We acknowledge the limited number of teacher participants in this study. However, it is important to note that the teachers in this study are enrolled as part of a first CS teacher certificate program in the state. Due to the recency of this certificate program and the level of commitment this program requires—two years, four courses, totaling 16 credit hours—the recruitment and retention of teacher participants has been challenging, which resulted in limited sample sizes. Still, there is great value in learning from this sample—results from this study will inform many such certificate programs for CS teachers that are emerging around the nation.

6.5 Conclusions

Findings from this study suggest that teachers who participated in a CS teacher certificate program recognized their roles as the agents of change in creating an equitable CS learning environment. However, teachers' definitions and discourses around equity mainly focused on equal participation and providing equal access to resources. And while discussing equitable teaching strategies, the participants emphasized the importance of considering students' backgrounds but mainly referred to students' prior knowledge and skills rather than their social, cultural, and political backgrounds. Thus, based on the justice-centered framework, the participants' perceptions about equity focused on the redistributive model and tended towards the lower end on the spectrum of socially just practices. Besides, while making attributions about inequities in CS classrooms, the participants showed the trend of focusing on factors at the individual level rather than at the structural level. These results suggest the need to help teachers develop a more in-depth understanding of equity issues beyond the scope of equal participation and form critical reflections that recognize the structural causes of inequities in CS education. Such conceptualization would provide the basis for implementing equitable practices that acknowledge students' wealth of social and cultural resources and devise learning activities to empower youth in CS classrooms and communities.

Specifically, to develop a comprehensive understanding of equity, current and future PD programs should explore ways to (1) introduce and help teachers differentiate the redistributive model and the relational model and (2) explicitly highlight the political attributes of CS education and its sociopolitical impact through readings, discussions, and micro-teaching. To facilitate the implementation of equitable practices, it is necessary to (1) conduct follow-up classroom observations and school visits to help teachers apply culturally relevant practices to classroom teaching, (2) assist teachers in collecting student feedback to inform future teaching, and (3) hold regular Professional Learning Community meetings that help teachers identify ways to learn about students' social and cultural backgrounds, as well as strategies to integrate equitable practices, such as culturally responsive teaching in their CS classrooms.

ACKNOWLEDGMENTS

We thank the undergraduate research assistants Lizethe Arce, Andrea Marella, Yucheng Zhu, Sasha Meng, and Rigoberto Lopez for their contributions, as well as Iris Kang who assisted with research through the Troy Tech internship program from Troy High School.

REFERENCES

[1] Eric M. Anderman, Gale M. Sinatra, and Gray DeLeon. 2012. The challenges of teaching and learning about science in the twenty-first century: Exploring the abilities and constraints of adolescent learners. *Stud. Sci. Educ.* 48, 1 (2012), 89–117. DOI: https://doi.org/10.1186/s12903-017-0470-6

[2] William Aspray. 2016. Recent efforts to broaden informal computer science education. In *Participation in Computing*. Springer, Cham, 147–163. DOI: https://doi.org/10.1007/978-3-319-24832-5_5

[3] Albert Bandura, C. Barbaranelli, G. V. Caprara, and C. Pastorelli. 2001. Self-efficacy beliefs as shapers of children's aspirations and career trajectories.*Child Dev.* 72, 1 (2001), 187–206. DOI: https://doi.org/10.1111/1467-8624.00273

[4] Quincy Brown and Amy Briggs. 2015. The CS10K initiative. *ACM Inroads* 6, 3 (2015), 52–53. DOI: https://doi.org/10.1145/2803178

[5] Qidong Cao, Thomas E. Griffin, and Xue Bai. 2001. The importance of synchronous interaction for student satisfaction with course web sites. *J. Inf. Syst. Educ.* 20, 3 (2001), 331–339.

[6] Flora Cornish, Alex Gillespie, and Tania Zittoun. 2014. Collaborative analysis of qualitative data. In *The SAGE Handbook of Qualitative Data Analysis*. SAGE Publications, Inc., London, 79–93. DOI: https://doi.org/10.4135/9781446282243.n6

[7] Emily Dawson. 2014. Reframing social exclusion from science communication: Moving away from "barriers" towards a more complex perspective. Retrieved from http://discovery.ucl.ac.uk/1469305/.

[8] Emily Dawson. 2017. Social justice and out-of-school science learning: Exploring equity in science television, science clubs, and maker spaces. *Sci. Ed.* 101, 4 (7 2017), 539–547. DOI: https://doi.org/10.1002/sce.21288

[9] Jean Decety and Jason M. Cowell. 2015. Empathy, justice, and moral behavior. *AJOB Neurosci.* 6, 3 (2015), 3–14. DOI: https://doi.org/10.1080/21507740.2015.1047055

[10] Jean Decety and Keith J. Yoder. 2016. Empathy and motivation for justice: Cognitive empathy and concern, but not emotional empathy, predict sensitivity to injustice for others. *Soc. Neurosci.* 11, 1 (2016), 1–14. DOI: https://doi.org/10.1080/17470919.2015.1029593

[11] Matthew A. Diemer and David L. Blustein. 2006. Critical consciousness and career development among urban youth. *J. Vocat. Behav.* 68, 2 (2006), 220–232. DOI: https://doi.org/10.1016/j.jvb.2005.07.001

[12] Matthew A. Diemer, Luke J. Rapa, Catalina J. Park, and Justin C. Perry. 2017. Development and validation of the critical consciousness scale. *Youth Societ.* 49, 4 (2017), 461–483. DOI: https://doi.org/10.1177/0044118X14538289

[13] Samuel B. Fee and Amanda M. Holland-Minkley. 2010. Teaching computer science through problems, not solutions. *Comput. Sci. Educ.* 20, 2 (2010), 129–144. DOI: https://doi.org/10.1080/08993408.2010.486271

[14] Paulo Freire. 2000. *Pedagogy of the Oppressed*. Verlag Herder. DOI: https://doi.org/10.1215/00382876-1472612

[15] Ursula Fuller, Charles Riedesel, Errol Thompson, Colin G. Johnson, Tuukka Ahoniemi, Diana Cukierman, Isidoro Hernán-Losada, Jana Jackova, Essi Lahtinen, Tracy L. Lewis, and Donna McGee Thompson. 2007. Developing a computer science-specific learning taxonomy. *ACM SIGCSE Bull.* 39, 4 (2007), 152–170. DOI: https://doi.org/10.1145/1345375.1345438

[16] Jinzhu Gao and Jace Hargis. 2010. Promoting technology-assisted active learning in computer science education. *J. Effect. Teach.* 10, 2 (2010), 81–93. Retrieved from https://www.uncw.edu/jet/articles/Vol10_2/Gao.pdf.

[17] Shernaz B. García and Patricia L. Guerra. 2004. Deconstructing deficit thinking: Working with educators to create more equitable learning environments. *Educ. Urb. Societ.* 36, 2 (2004), 150–168. DOI: https://doi.org/10.1177/0013124503261322

[18] Geneva Gay and Kipchoge Kirkland. 2003. Consciousness and self-reflection in preservice teacher education. *Theor. Pract.* 42, 3 (2003), 181–187. DOI: https://doi.org/10.1207/s15430421tip4203

[19] Geneva Gay and Kipchoge Kirkland. 2003. Developing cultural critical consciousness and self-reflection in preservice teacher education. *Theor. Pract.* 42, 3 (8 2003), 181–187. DOI: https://doi.org/10.1207/s15430421tip4203_3

[20] Joanna Goode. 2008. Increasing diversity in k–12 computer science. In *ACM SIGCSE Bulletin*, Vol. 40. ACM Press, New York, New York, 362. DOI: https://doi.org/10.1145/1352322.1352259

[21] Joanna Goode, Gail Chapman, and Jane Margolis. 2012. Beyond curriculum: The exploring computer science program. *ACM Inroads* 3, 2 (2012), 47–53. DOI: https://doi.org/10.1145/2189835.2189851

[22] Joanna Goode, Jane Margolis, and Gail Chapman. 2014. Curriculum is not enough: The educational theory and research foundation of the exploring computer science professional development model. In *Proceedings of the 45th Annual ACM SIGCSE Conference*. 493–498. DOI: https://doi.org/10.1145/2538862.2538948

[23] Suchi Grover and Roy Pea. 2013. Computational thinking in K-12: A review of the state of the field. *Educ. Res.* 42, 1 (2013), 38–43. DOI: https://doi.org/10.3102/0013189X12463051

[24] Sandra Harding. 2009. Postcolonial and feminist philosophies of science and technology: Convergences and dissonances. *Postcolon. Stud.* 12, 4 (12 2009), 401–421. DOI: https://doi.org/10.1080/13688790903350658

[25] Martin Hoffman. 2001. *Empathy and Moral Development: Implications for Caring and Justice*. Cambridge University Press, New York, NY. Retrieved from https://books.google.com/books?hl=en&lr=&id=ose5vtvDoBoC&oi=fnd&pg=PR9&dq=hoffman+2001&ots=SA3V124m17&sig=AJ09ib28cWz1EE7Wahh35wndPnQ.

[26] Hsiu Fang Hsieh and Sarah E. Shannon. 2005. Three approaches to qualitative content analysis. *Qualit. Health Res.* 15, 9 (2005), 1277–1288. Retrieved from DOI: https://doi.org/10.1177/1049732305276687

[27] Hanna Kallio, Anna-Maija Pietilä, Martin Johnson, and Mari Kangasniemi. 2016. Systematic methodological review: Developing a framework for a qualitative semi-structured interview guide. *J. Adv. Nurs.* 72, 12 (12 2016), 2954–2965. DOI: https://doi.org/10.1111/jan.13031

[28] Karlheinz Kautz and Uffe Kofoed. 2004. Studying computer science in a multidisciplinary degree programme: Freshman students' orientation, knowledge, and background. *J. Inf. Technol. Educ.* 3 (2004), 227–244. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&AuthType=ip,shib&db=eric&AN=EJ848657&site=ehost-live&scope=site%0Ahttp://jite.org/documents/Vol3/v3p227-244-133.pdf.

[29] Klaus Krippendorff. 2012. *Content Analysis: An Introduction to Its Methodology*. Vol. 79. Sage Publications, Thousand Oaks, CA. DOI: https://doi.org/10.2307/2288384

[30] G. Ladson-Billings. 1995. But that's just good teaching! The case for culturally relevant pedagogy. *Theor. Pract.* 34, 3 (1995), 159–165. DOI: https://doi.org/10.1080/00405849509543675

[31] Okhee Lee and Cory A. Buxton. 2010. Diversity and equity in science education. In *Teachers College Press*. Teachers College Press, New York, NY, 60–79.

[32] Beth L. Leech. 2002. Asking questions: Techniques for semistructured interviews. *Polit. Sci. Polit.* 35, 04 (12 2002), 665–668. DOI: https://doi.org/10.1017/S1049096502001129

[33] Jane Margolis, R. Estrella, J. Goode, J. Holme, and K. Nao. 2008. *Stuck in the Shallow End: Education, Race, and Computing*. The MIT Press, 71–95.

[34] Jane Margolis, Joanna Goode, and Gail Chapman. 2015. An equity lens for scaling. *ACM Inroads* 6, 3 (2015), 58–66. DOI: https://doi.org/10.1145/2794294

[35] Jane Margolis, Joanna Goode, Gail Chapman, and Jean J. Ryoo. 2014. That classroom "magic."*Commun. ACM* 57, 7 (2014), 31–33. DOI: https://doi.org/10.1145/2618107

[36] Jane Margolis, Jean J. Ryoo, Cueponcaxochitl Dianna Moreno Sandoval, Clifford Lee, Joanna Goode, and Gail Chapman. 2012. Beyond access: Broadening participation in high school computer science. *ACM Inroads* 3, 4 (2012), 72–78. DOI: https://doi.org/10.1145/2381083.2381102

[37] Richard Milner. 2015. *Rac(e)ing to Class: Confronting Poverty and Race in Schools and Classrooms*. Harvard Education Press, Cambridge, MA.

[38] Daniel Morales-Doyle. 2017. Justice-centered science pedagogy: A catalyst for academic achievement and social transformation. *Sci. Educ.* 101, 6 (2017), 1034–1060. DOI: https://doi.org/10.1002/sce.21305

[39] Thomas M. Philip and Flavio S. Azevedo. 2017. Everyday science learning and equity: Mapping the contested terrain. *Sci. Educ.* 101, 4 (2017), 526–532. DOI: https://doi.org/10.1002/sce.21286

[40] W. James Potter and Deborah Levine-Donnerstein. 1999. Rethinking validity and reliability in content analysis. *J. Appl. Commun. Res.* 27, 3 (1999), 258–284. DOI: https://doi.org/10.1080/00909889909365539

[41] Jean J. Ryoo, Jane Margolis, Clifford H. Lee, Cueponcaxochitl D. M. Sandoval, and Joanna Goode. 2013. Democratizing computer science knowledge: Transforming the face of computer science through public high school education. *Learn. Media Technol.* 38, 2 (2013), 161–181. DOI: https://doi.org/10.1080/17439884.2013.756514

[42] Kimberly A. Scott, Kimberly M. Sheridan, and Kevin Clark. 2015. Culturally responsive computing: A theory revisited. *Learn. Media Technol.* 40, 4 (2015), 412–436. DOI: https://doi.org/10.1080/17439884.2014.924966

[43] Kimberly A. Scott and Mary Aleta White. 2013. COMPUGIRLS' standpoint: Culturally responsive computing and its effect on girls of color. *Urb. Educ.* 48, 5 (2013), 657–681. DOI: https://doi.org/10.1177/0042085913491219

[44] Niral Shah, Colleen M. Lewis, Roxane Caires, Nasar Khan, Amirah Qureshi, Danielle Ehsanipour, and Noopur Gupta. 2013. Building equitable computer science classrooms. In *Proceedings of the 44th ACM Technical Symposium on Computer Science Education (SIGCSE'13)*. 263–268. DOI: https://doi.org/10.1145/2445196.2445276

[45] Kimberly M. Sheridan, Kevin Clark, and Asia Williams. 2013. Designing games, designing roles: A study of youth agency in an urban informal education program. *Urb. Educ.* 48, 5 (2013), 734–758. DOI: https://doi.org/10.1177/0042085913491220

[46] Renee Smit. 2012. Towards a clearer understanding of student disadvantage in higher education: Problematising deficit thinking. *High. Educ. Res. Dev.* 31, 3 (2012), 369–380. DOI: https://doi.org/10.1080/07294360.2011.634383

[47] Angela Sweeney, Kathryn E. Greenwood, Sally Williams, Til Wykes, and Diana S. Rose. 2013. Hearing the voices of service user researchers in collaborative qualitative data analysis: The case for multiple coding. *Health Expect.* 16, 4 (2013). DOI: https://doi.org/10.1111/j.1369-7625.2012.00810.x
[48] Evan Thompson. 2001. Empathy and consciousness. *J. Conscious. Stud.* 8, 5–7 (2001), 1–32.
[49] Char Ullman and Janet Hecsh. 2011. These American lives: Becoming a culturally responsive teacher and the "risks of empathy."*Race Ethnic. Educ.* 14, 5 (2011), 603–629.
[50] Sepehr Vakil. 2018. Ethics, identity, and political vision: Toward a justice-centered approach to equity in computer science education. *Harvard Educ. Rev.* 88, 1 (3 2018), 26–52. DOI: https://doi.org/10.17763/1943-5045-88.1.26
[51] Roderick Watts, Matthew Diemer, and Adam Voight. 2011. Critical consciousness: Current status and future directions. *New Dir. Child Adolesc. Dev.* 134 (2011), 43–57.

Received July 2019; revised February 2020; accepted June 2020