Promoting High School Teachers' Self-efficacy and the Understanding of Equity Issues in CS Classrooms

Ninger Zhou
School of Education
University of California, Irvine
Irvine, CA, USA
Email:ningerz@uci.edu

Debra Richardson
Donald Bren School of Information and Computer Sciences
University of California, Irvine
Irvine, CA, USA
Email: djr@ics.uci.edu

Mark Warschauer
School of Education
University of California, Irvine
Irvine, CA, USA
Email: markw@uci.edu

***Abstract*—Effective and equitable CS teaching in classrooms is contingent on teachers' high-levels of self-efficacy in CS as well as a robust understanding of equity issues in CS classrooms. To this end, our study examined the influence of a professional development (PD) course, Teaching Exploring Computer Science (TECS), on promoting teacher self-efficacy and equity awareness in CS education. This nine-week PD was offered in a hybrid format, delivering on-line and face-to-face classes to high school teachers across various disciplines who served under-represented students. The participants completed a self-efficacy survey focusing on their ability to teach ECS, both before and after the course. Results showed that teachers' self-efficacy in the content knowledge and pedagogical knowledge of ECS significantly increased as a result of taking the course. We also evaluated teacher's understanding of the equity issues by conducting a content analysis of their reflection essays written at the end of the course. Four major themes emerged from the content analysis, highlighting the impact of equitable practices on CS participation. This research demonstrates the role of a professional development course in promoting teachers' self-efficacy beliefs in teaching CS and their understanding of the equity issues and presents tools for assessing teachers' development in these areas.**

***Index Terms*—Self-efficacy, Equity, Professional Development, Exploring Computer Science**

I. INTRODUCTION

CS education at the secondary school level contributes to the equality of the CS education pipeline and promotes fundamental skills such as computational thinking [1]. Among others, the Exploring Computer Science (ECS) curriculum has been designed and widely adopted around the nation to promote CS education in secondary schools through broadening participation, instilling interest, and enhancing equity in CS classrooms [2]. Because the ECS curriculum is intended to engage students' interest and inspire their passion for computing, the effective implementation of the ECS curriculum is not solely contingent upon teacher's content knowledge—teachers' self-efficacy in teaching CS and the in-depth understanding of the equity issues in CS classrooms are also critical prerequisites for effective CS instruction [3]. However, there has been a dearth of research on the development of teachers' self-efficacy in teaching ECS and on the teachers' understanding of the equity issues in CS education. To further this research, we engaged in-service high school teachers in a professional development course—Teaching Exploring Computer Science (TECS) and addressed research questions in: 1) What is the influence of the TECS class on the high school teachers' self-efficacy in the content and pedagogical knowledge of teaching TECS? 2) What are the high school teachers' understandings of the equity issues in CS education after completing the TECS course?

II. BACKGROUND

Efforts devoted to broadening participation in formal CS education has focused on issues related to access in the past decade–offering high quality CS courses in more schools and attract a wider audience of students, especially females and underrepresented students [4]. Propelled by the national initiatives such as CS10K, substantive and high quality CS curriculum have been developed to facilitate the understanding of essential CS concepts, deviating from the overemphasis on technology literacy in traditional CS courses. However, the challenges to broadening participation still remain in the other aspects of access-the lack of professional development programs to nurture effective CS teachers, and the complexities involved in the equity issues in CS classrooms. Therefore, much of the existing research on CS education has recognized the importance of preparing teachers with the content and pedagogical knowledge of teaching CS and the strategies to promote equity practices [3]. However, research in other STEM disciplines has shown that teachers' self-efficacy beliefs in the content and pedagogical knowledge are of equal if not greater importance than the mastery of such knowledge [5]. On the one hand, self-efficacy beliefs are predictive of the teachers' persistence and effort levels when challenges arise [6]; on the other hand, teachers' self-efficacy in a discipline provide models for students and facilitates students' self-efficacy in the same discipline [7]. Therefore, examining the teachers' development of self-efficacy in the content and pedagogical knowledge of teaching ECS is necessary and can provide information on how to structure PD programs to facilitate such development.

A. *Self-efficacy in CS Teachers*

Teacher self-efficacy is an important construct in teacher education and has been found to not only influence student learning, but also predict teaching behaviors and teachers' persistence in the face of challenges [8], [9]. For example, several prior studies have identified that teacher efficacy has

978-1-5386-1363-4/18/$31.00©2018 IEEE

predictive roles in teacher burnout, student achievement and students' self-efficacy [10]. However, although the research on teacher self-efficacy has been established for decades in other disciplines, the research for CS teachers' self-efficacy has been limited. In this section, we draw on the research from other fields to inform the framework for the current study.

Self-efficacy describes the extent to which one believes that one can successfully perform a task in a specific situation or area [6]. In the context of teacher self-efficacy, one strand of research examines teachers' belief in whether educational practices can influence student learning [10]. In comparison, another strand of research is more focused on Bandura's definition of self-efficacy and measures teacher self-efficacy as teachers' belief in their ability to complete certain tasks in teaching [8], [11]. These two types of theoretical backgrounds have resulted in variances in the construction of teacher self-efficacy surveys. However, recent developments on teacher self-efficacy have suggested adhering to the original definition of self-efficacy as defined by Bandura—one's belief in the ability to successfully accomplish a task [8]. In addition, self-efficacy is domain specific in nature, where narrowly defined measures are more predictive of future behaviors than those covering a broad spectrum without defining specific tasks or behaviors [8], [9]. Therefore, in this study, we created content-specific measures and followed Bandura's model on constructing self-efficacy surveys to examine teachers' self-efficacy in teaching ECS [11].

To identify the content-specific items for the self-efficacy survey, we drew on the teacher education literature that identified the content knowledge, pedagogical knowledge and pedagogical content knowledge (PCK) as essential to the development of teacher knowledge [8], [12]. While PCK or the "adaptation of subject matter knowledge for pedagogical purposes" [13, p.7] is an important aspect of teacher knowledge, it is built upon teachers' content knowledge and the pedagogical knowledge [13], [14]. Therefore, in the current study, instead of examining teachers' self-efficacy in PCK, we focused on the teachers' self-efficacy in the content knowledge and pedagogical knowledge of teaching ECS.

To promote teachers' self-efficacy, the social cognitive theory has suggested that it is important to tap into the four major sources of self-efficacy, including mastery experiences, vicarious experiences, physiological state and social persuasion [8]. Among these four sources of self-efficacy, the mastery experiences have been identified as the most influential factor contributing to teachers' self-efficacy. For example, [5] found that mastery experiences were especially beneficial for developing novice teachers' self-efficacy judgments. Similarly, several studies in the filed of science teacher self-efficacy have found that professional development programs that support the major sources of self-efficacy and emphasize both the content knowledge and pedagogy practices tend to significantly promote teacher efficacy as measured in personal teaching efficacy and outcome expectancy [15]. Therefore, teacher training programs that aim at promoting teachers' self-efficacy beliefs should provide experiences that cater to one or several of the major sources of self-efficacy, especially providing mastery experiences [9].

B. Equity in CS Education

Promoting equity has been at the forefront of CS education and become the focus of many national initiatives such as CS10K [4]. However, research on the equity issues in CS education has been limited. Therefore, in this study, we first draw on the relevant research in science education, which shows that factors such as the growing diversity of student populations in schools, the achievement gaps among demographic groups, and the importance of scientific literacy in the modern world have imposed urgency and challenges to equity [16]. To address these issues, the science education community has called for discipline-specific and diversity-oriented approaches to bring about science for all students, premised on the fact that high level of performance and achievement are obtainable for all students regardless of the students' cultural, linguistic, and socioeconomic backgrounds. This premise requires educators to recognize that achievement gaps in science among different demographic groups are more likely to be the results of the varying amount of learning opportunities available in the students' environment, rather than students' innate abilities stereotyped by cultural biases. Therefore, educators need to consider the alignment of the students' cultural and linguistic resources and the classroom practices, value the experiences that students bring in the classroom, interpret science knowledge in accordance with students' cultural backgrounds, and provide resources to support science learning for all students [16]. In summary, the science education research has highlighted the urgency of addressing equity issues through providing equal access and promoting equitable practices in classrooms for all students.

Perhaps not coincidentally, a similar constellation of factors have challenged the equitable practices in CS education [4]. In alignment with the science education research that highlighted the importance of equal access to disciplinary resources, pioneering work in CS education has shown that the unequal access to resources such as technology tools and curriculum has caused disparities in CS education, disadvantaging students from low-SES backgrounds and underrepresented ethnic groups [17]. Informed by these disparities, national initiatives and research efforts have been devoted to creating inspiring and engaging curriculum to provide students from diverse backgrounds equal access to CS resources [4].

Under the broader context of the remarkably low percentage of females and underrepresented minorities in CS classrooms and beyond, it is easy to fall under the impression that promoting access and broadening participation–getting more students from diverse background in CS classrooms–has addressed much of the equity issues. However, equity issues are also deeply rooted in social and cultural practices [16]. For example, educators and students' faulty beliefs about what types of students can excel in CS have also prevented students from diverse background to participate equally in CS education [17]. Therefore, in addition to creating equal access, it is also important to promote equitable teaching practices such as changing the social interaction dynamics in classrooms and encourage educators and the community to form a more comprehensive view about human cognition–recognizing that all students can understand and work with CS problems. It's just that students need different types of support based on their prior experiences with CS.

Besides, creating equitable CS classrooms has been complicated by the ubiquitous and complex nature of CS. On the one hand, although CS is a relatively new discipline, its applications have permeated our society and are more deeply rooted in our daily life than traditional disciplines such as math and science [18]. As a result, students with more resources are more likely to be equipped with the essential prerequisites to CS education, whereas students who are from underprivileged backgrounds are likely to suffer due to the lack of CS experiences in their home environment and social life [19].

On the other hand, CS as a discipline is considered to be innately challenging and requiring unique mindsets and approaches to problem solving [3]. Such deviation from the traditional disciplines predicates that students who are without CS experiences in their home and community are not likely to acquire problem solving strategies unique to CS elsewhere. In addition, teachers' deficit views about students' abilities are prone to be even more prevalent in CS than in the other disciplines, where students' level of understanding is difficult to measure using traditional methods [20]. For example, because CS problems are often complex and involving multiple solutions, the students' seemingly mistaken early stage trials may lead to promising solutions. This phenomenon has created challenges for educators to maintain an equity stance in CS education because it may reinforce the belief that some students just will not ”get it”, when in fact the students are approaching the problem from a different angle [21]. Therefore, it is important to bridge the connection between creating access opportunities and the in-depth understanding of students' problem-solving processes in CS –forming a recognition that all students can become effective CS problem solvers and CT thinkers as long as they are given proportionate time and support.

In summary, research on equity in science education and computer science education has suggested the imperative of investigating teachers understanding of equity issues in CS classrooms, especially on issues related to equal access and equitable teaching practices that value the background students bring in the classroom. Along this line of research, prior research in CS education has shown that high school teachers' reflections on the equity issues tend to focus on the material aspect (the access to the course content and the access to the quality instruction) and the non-material aspects (the access to the identities as computer scientists and the access to the peer relationships) [22]. In this study, we analyzed high school teachers' reflections on the equity issues in CS education and intended to enrich the frameworks proposed in previous work.

III. Methods

A. Participants

The participants are high school teachers from various disciplines in schools that mainly serve underrepresented minority students in Southern California. A total of 27 teachers attended the TECS PD course. The participants' prior teaching experiences and demographic information are presented in Table I and Table II. Due to factors beyond our control (i.e. sick leave, personal scheduling issues), 24 teachers completed the course and filled out both the pre and post self-efficacy surveys.

TABLE I
Participants' Teaching Experiences

Categories		Count
Credentialed Subjects *		
	Math	14
	English	3
	Science	4
	World languages	1
	Business	2
	Technology related credentials [a]	4
	Special Education	1
	Social Sciences	1
Years of Teaching		
	1-5 year	3
	5-10 year	6
	10-15 year	7
	15-20 year	5
	21 years and above	3

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

TABLE II
Participants' Demographic Information

Categories		Count
Gender		
	Male	16
	Female	8
Ethnicity		
	Asian	5
	White	14
	Hispanic	4
	Other- W Middle Eastern	1

B. Measures

1) Self-efficacy Survey: To assess the teachers' self-efficacy beliefs, we designed a self-efficacy survey that included items on the content knowledge and pedagogical knowledge of teaching ECS.

The content knowledge section has 20 items in total and was developed based on the CS domain content identified in the Praxis Computer Science Content Validity Survey (PCSCV). The PCSCV survey was distributed by ETS and obtained insights from a national committee of CS teachers, educators, and national CS organizations on the major domain knowledge appropriate for entry-level CS teachers. Therefore, the content items identified in this survey were considered as appropriate for the content knowledge self-efficacy items for the current study. To align the content knowledge items with the scope of the ECS curriculum, we selected the representative items from the PCSCV survey that reflect the learning objectives in the ECS curriculum. To construct the survey, we followed the model proposed in [11]'s work on constructing self-efficacy items while incorporating the content knowledge items selected from the PCSCV survey. The internal consistency of the content knowledge self-efficacy items are Cronbach's alpha=0.96. Sample items include: Based on your current understanding and skills, please rate your confidence in your ability to perform the following tasks: I can explain how to use sorting algorithm to solve problems. I can identify the major criteria for evaluating the quality of a website.The participants rated the items on a 5-point scale that ranges from Strongly Disagree(point value of 1) to Strongly Agree (point value of 5).

The pedagogical knowledge section has 10 items in total and was developed based on the model proposed in previous research on teaching self-efficacy in STEM [23]. Previous work has examined teachers' teaching self-efficacy from the personal teaching efficacy and outcome expectancy aspects [23]. However, considering that recent developments on teacher efficacy have highlighted the importance of adhering to the original definition of self-efficacy and separating outcome expectancy from teacher self-efficacy measures [8], we mainly focused on the personal teaching efficacy in this study. We adapted the personal teaching efficacy items established in math and science to reflect teachers' belief in their ability to successfully apply teaching strategies related to the CS classroom, such as inquiry based learning and equity practices. The internal consistency of the items are Cronbach's alpha=0.71. Sample items include: Based on your current understanding and skills, please rate your confidence in your ability to perform the following tasks: I can effectively monitor students' engagement in computer science learning activities. I can use inquiry-based teaching methods to promote student learning in computer science classes.The participants rated the items on a 5-point scale that ranges from Strongly Disagree(point value of 1) to Strongly Agree (point value of 5).

2) CS Education Equity Essay: Each participant completed a 2-page (500-600 words) reflection essay on the equity issues in CS education at the end of the TECS course. The instructions given for the reflection essay allowed the teachers to draw from their observations of the equity issues in CS education either at their schools or in the society. While writing the essays, the teachers can refer to any online resources, and/or the reading materials assigned during the course, including Stuck in the Shallow End [17], and Racing to Class [24] . There were no requirements on the types of equity issues that should be discussed in the paper.

C. Procedures

The participants engaged in the 9-week Teaching Exploring Computer Science (TECS) professional development course in a hybrid format involving online asynchronous learning modules in learning management systems, online synchronous classes on a video conferencing platform, and three monthly face-to-face classes. The learning experiences in the TECS PD course were designed to highlight the main thrusts of the ECS curriculum: Inquiry, Equity, and CS concepts. In online asynchronous modules, the participants completed weekly assignments including reading reflection essays on book chapters related to equity in CS education (i.e. chapters from Stuck in the Shallow End), computing artifacts (i.e. webpages created in HTML/CSS, animation/games created in the Scratch environment), and lessons adapted from the ECS curriculum that can be used in the teachers' classrooms. In the online synchronous classes and the face-to-face classes, the teachers reflected on the teaching demonstration 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 hands-on activities such as making a PBJ sandwich to introduce the concepts of algorithms) and the experiences of creating computing artifacts as learners. Using PD frameworks suggested in previous research for the ECS curriculum [3], the current study engaged the participants in the Teacher-Learner-Observer model during the online and face-to-face classes.

Immediately before and after the course, the participants took a pre and post survey to assess their self-efficacy in the content knowledge and pedagogical knowledge of teaching Exploring Computer Science. Because previous research has suggested that in a pre-post research design, participants may experience response-shift bias, where their self-evaluation criterion may change after experiencing the interventions, resulting in discrepancies between the actual pre-post change and the survey responses [25]. To ameliorate the impact of such response-shift bias, the current study implemented a retrospective pre and post format in the post survey design. Thus, in addition to having the participants rate their self-efficacy after completing the course, we also asked the participants to rate their self-efficacy prior to taking the course based on their current understanding of the ECS content knowledge in the post survey.

In addition, as described above, at the end of the TECS course, the participants completed a 500-600 words reflection essay on the equity issues in CS education.

D. Data Analysis

1) Self-efficacy Survey: The total score of the self-efficacy survey was used in the analysis. We conducted a series of paired sample t-test for the content knowledge self-efficacy survey and pedagogical knowledge self-efficacy survey. Because the teachers gave retrospective before and after ratings in the post surveys, we conducted two sets of paired sample t-test to compare the pre survey vs. the retrospective-after rating, and the retrospective-before vs. the retrospective-after ratings for each survey.

2) Equity Reflection Essay: 24 participants completed the reflection essays, which were examined using the content analysis method [26]. Because the goal of the content analysis is exploratory where we identified emerging themes in the participants' reflections of the equity issues, open coding was used during the content analysis and was conducted in iterative cycles [27]. In the first cycle of coding, two researchers worked independently and assigned preliminary codes to the text relevant to the equity issues in CS education. After doing such open coding for five essays, the two researchers discussed and consolidated the preliminary codes. Then one researcher assigned the consolidated codes to the remaining essays. The researcher also generated new codes in the process when the existing codes did not fit with a particular group of text. In the second cycle of coding, the researcher read all the text under each code and either combined or split the codes into categories or subcategories [28].

To establish the reliability of the codes, after the codes were organized as a hierarchical coding structure, a second researcher randomly selected 25% of the essays and applied the existing codes to the text. The inter-rater reliability showed that the two researchers reached 97% agreement on the application of the codes.

IV. Results

A. Self-efficacy

To answer the first research question on the influence of the TECS class on the high school teachers' self-efficacy in the content and pedagogical knowledge of teaching TECS, we compared the participants' ratings on the pre and post self-efficacy surveys.

1) Content Knowledge Self-efficacy: There are 20 items in the content knowledge self-efficacy survey. Each item was rated on a 5-point scale that ranges from 1 to 5. Therefore, the total score of the content knowledge self-efficacy survey ranges between 20 to 100. Results from the paired sample t-test show that the participants increased significantly from the pre survey to the retrospective-after survey, $t(23)=14.17$, $p<0.001$, $d=2.70$. The participants' self-efficacy ratings also increased significantly from the retrospective before to retrospective after survey, $t(23)=8.66$, $p<0.001$, $d=1.5$ (The descriptive statistics are shown in Table III).

2) Pedagogical Knowledge Self-efficacy: There are 10 items in the pedagogical knowledge self-efficacy survey. Each item was rated on a 5-point scale that ranges from 1 to 5. The total score of this survey ranges from 10 to 50. The paired sample t-test of the teaching self-efficacy survey shows that the participants increased significantly from before to after taking the TECS course, $t(23)=3.82$, $p=0.001$, $d=0.96$. The retrospective before and after ratings also increased significantly, $t(23)=7.20$,$p<0.001$, $d=1.53$. (Descriptive statistics are shown in Table III).

B. CS Education Equity Essay

To answer the second research question on the high school teachers' understandings of the equity issues in CS education, we examined the results from the content analysis. As shown in Table IV, the coding categories generated from the content analysis of the participants' reflection essays include 1) *Students' Role in Equity*: Students' beliefs and characteristics influence the equity in CS education 2) *Teachers' Role in Equity*: Teachers' beliefs and practices influence the equity in CS education 3) *The Uniqueness of CS as a Discipline*: the unique characteristics of CS contribute to the inequality in CS education 4) *The Societal Influences on Equity*: the belief system and resources of the society impact the teachers' equitable practices and the students' equitable participation in CS.

TABLE III
Descriptive Statistics of the Pre and Retrospective Before and After Content Knowledge and Pedagogical Knowledge Self-efficacy Surveys

Survey		N	M	SD
Content				
	Pre Survey	24	33.54	21.22
	Retrospective-Before	24	53.08	22.36
	Retrospective-After	24	84.75	9.40
Pedagogical				
	Pre Survey	24	33.83	4.26
	Retrospective Before	24	26.17	8.95
	Retrospective After	24	37.88	4.20

Under the *Students' Role in Equity* category, the subcategories focused on the students *Personal Beliefs/stereotypes about CS* (i.e. female students perceive themselves as not suited for CS classes), the influence of the students' *Cultural and Demographic Background* on their development (i.e. low SES students have inadequate prior knowledge), and the *Inequality in Students' Participation in CS* (i.e. White male students are the majority of the CS classes). Among these categories, the teachers discussed the *Inequality in Students' Participation in CS* the most (65.38%), suggesting that the teachers in our study consider students' equal access and participation in CS education programs as the most prevalent issue in students' role in equity.

The *Teachers' Role in Equity* category, which essentially describes teachers' agency in promoting the equity in CS classrooms, involves the *Personal Beliefs/Stereotypes about CS*, such as what types of students should attend CS classes. The teachers attributed the development of such stereotypes to the lack of exposures to the CS discipline and CS-related professional development. In addition, the teachers mentioned that the TECS professional development changed their stereotypes and helped them to see that CS is for all students. The teachers also discussed *Equitable Teaching Practices* (i.e. recruiting diverse students for CS classes, or keeping students' diverse background in mind while teaching). There were also discussions related to *Teacher Community*, where references were made to the importance of learning from and contributing to the teacher community regarding equitable practices (i.e. the need to learn from other teachers on promoting equity in CS classes, influence peers and change other teachers' stereotypes about CS). As shown in Table IV, under the *Teachers' Role in Equity* category, most of the discussions (66.23%) mentioned the intention of implementing a variety of *Equitable Teaching*

TABLE IV
CODING CATEGORIES

Categories/Subcategories	Excerpts of Coded Examples	Percent (%) *
Students' Role 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' Role 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 the 2017 we dont 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
Inequality in CS Education influences CS as a Discipline	"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

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

Practices as a result of participating in the TECS PD, which changed their personal beliefs about CS education.

The category of the *Unique Characteristics of CS as a Discipline* focuses on the main characteristics of CS that make it an important yet challenging discipline. For example, while acknowledging the *The Importance of CS*, which teaches a variety of important and fundamental skills, such as critical thinking and computational thinking, the participants also described that *CS is Constantly Changing* and that *CS Content is Challenging*. Such uniqueness of the discipline, the participants observed, may have led to inequality in the students' and teachers' access to CS education (i.e. the field is constantly changing, making it difficult for the teachers and students to keep up; the curriculum has to change constantly to keep up with the field of CS). Among the subcategories, most of the discussions were focused on *The Importance of CS* (77.78%), indicating that the teachers were able to recognize the necessity to prepare students with the fundamental skills taught in CS. However, the low percentage of *CS Content is Challenging* statements may suggest that teachers did not necessarily gave high priority to the influences of the challenging nature of CS on equity issues.

The category of the *Societal Influences on Equity* focused on systemic factors, such as the society, the district, and the school's beliefs and practices that contribute to the inequality in CS education. The participants described that there are *Societal Stereotypes and Misconceptions about CS* (i.e. the society tends to perceive women as less suitable for CS than men), the *Lack of Resources/Curriculum in the System* (i.e. many schools don't offer CS classes), the *Lack of Teacher Training in the System* (i.e. there are very few CS PD programs available), and *The System Needs to Provide CS Education for All*. Notably, in the subcategory of the *Inequality in CS Education Influences CS as a Discipline*, the participants described the interplay between the students' participation in CS and the inequality in the CS discipline/industry and society. For example, the participants suggested that the inequality in the CS workforce can reinforce the stereotypes of a "CS person" and prevent students, especially female and underrepresented students from attending CS courses. In addition, the participants observed that the CS discipline and the society would in turn suffer from the inequality and lack of diversity in CS education. Among the subcategories, most of the discussions were focused on the *Societal Stereotypes and Misconceptions about CS* (34.07%), showing that when examining the relationship between the society and equity, teachers in our study were most concerned with the belief systems in the students' environment on their equitable participation in CS education.

V. Discussion

A. Teachers' Self-efficacy

This study builds on previous research on teacher self-efficacy and CS education by demonstrating self-efficacy surveys that can be used to assess the changes in teachers' self-efficacy in teaching CS. The findings from this research showed that teachers who participated in the TECS course increased significantly on the self-efficacy in the content and pedagogical knowledge of TECS from before to after taking the course. The significant increase in self-efficacy is consistent with prior research that identified significant improvement in teachers' self-efficacy through professional development in STEM areas [5]. This current study also differs from the previous research by including tasks that are directly related to the CS content in the self-efficacy survey and may better reflect the changes in self-efficacy as a domain specific construct.

Based on the previous research, a potential rationale for the teachers' change in self-efficacy is that the professional development program in the current study provided mastery experiences, one of the most prominent sources of developing teachers' self-efficacy [6], [8]. For example, the hybrid courses in this program may have contributed to the significant gains in teachers' content and pedagogical knowledge self-efficacy by engaging teachers in creating computing artifacts using the content knowledge and practiced teaching strategies in micro-teaching sessions.

Another potential source for the improvement of self-efficacy is vicarious experiences, where the teachers observed teaching strategies appropriate for the TECS content through experiencing the ECS content as learners (i.e. applying the Teacher-Learner-Observer model [3]) and watching the instructor who is an experienced ECS expert teacher from non-CS background during the online synchronous classes and the face-to-face classes. The similarity between the model and the self has been identified as a key factor in gaining self-efficacy through vicarious experiences [8], which is the case in this professional development program–the instructor is similar to the participants in terms of the profession and teaching experiences.

It is also necessary to explore if providing experiences that align with the other sources of self-efficacy can enhance teachers' self-efficacy in teaching ECS, such as through professional learning communities where mentors and peers can provide social persuasion for the teachers.

B. Teachers' Understanding of the Equity Issues in CS Education

The findings from this research corroborate previous literature by showing that the equity issues in CS education are multidimensional, encompassing the material and non-material dimensions [22]. This study also builds on previous research by showing that the participants interpreted the equity issues from the dimensions of the teachers, the students, the CS discipline, and the society. In addition, the participants were able to identify the bi-directional relationship between the system and the agents within the systems (i.e. the teachers and the students): the inequality in the system reinforces the students' unequal participation in CS education; the inequality in CS education in turn exerts negative impact on the system. Such a finding implies the necessity to help teachers identify the disciplinary and societal impact on their equitable practices and the types of strategies that can be implemented to ameliorate the negative impacts from the system.

Besides, under each of the four major categories, the teachers most frequently discussed the *Inequality in Students' Participation in CS*, *Equitable Teaching Practices*, *The Importance of CS*, and *Societal Stereotypes and Misconceptions about CS* subcategories respectively. In alignment with findings from the science and computer science education research, teachers' discussion of these subcategories demonstrated understanding of the mechanisms behind the equity issues –recognizing the urgency of addressing equity issues through broadening participation, providing equal access, and promoting equitable practices in classrooms for all students [29].

Most notably, the teachers described both the equal access and equitable teaching practice issues in CS education. They mainly centered on the phenomenon that students from demographic groups that are traditionally identified with CS are more likely to enroll and be confident in doing well in CS classes, whereas students from demographic groups that are traditionally considered under-performing in these areas may not consider signing up for CS courses. The teachers' discussion of such disparity in equal participation is consistent with previous research that showed even after students from traditionally underrepresented groups are enrolled in CS classes, they tend to be reinforced by the implicit cultural stereotypes and shy away from being actively engaged in CS activities, extending the vicious cycle of inequality in equal access [17].

While the teachers acknowledged the importance of equal access, their understanding of the influence of CS as a challenging discipline on the equitable practices in CS classrooms can be further developed and strengthened. For example, most of the discussions on equitable practices were centered on reaching out to more diverse students during recruitment and the necessity to consider the students' diverse background. Few statements connected the challenging nature of CS and the equitable practices in classrooms. However, there are deep connections between the social/cultural influences and the equity teaching practices [16]. Additionally, due to the complex nature of CS and social/cultural influences, teachers are particularly prone to form a deficit view about students' abilities in CS, a great obstacle to equitable teaching practices [29]. Besides, while a deficit view is relatively easier to be contradicted in science and math as the solutions are likely to be exhaustive and within teachers repertoire, such views are particularly difficult to counter in CS due to the multitude of possible solutions/algorithms to a given problem. Quite often, a seemingly faulty early prototypic solution may have great value and lead to something innovative later on. As a result, holding deficit assumptions about students' understanding and performance in CS classrooms can create devastating impact on equitable teaching practices. Thus, teachers' recognition of the value of the students' cultural background and knowledge, as well as the need to counter the deficit view of students' abilities are the key to equitable practices in CS classrooms [16], [17]. This is especially true considering that the theoretical advances on the multi-dimensionality of human cognition have highlighted the need to understand how each student may approach problems differently based on their prior knowledge and background. Therefore, to promote teachers' understanding of equity issues in CS classrooms, it is important to help them see the value of students' background knowledge, develop an in-depth understanding of students' problem-solving processes in CS, and counter deficit views to recognize that all students can engage in effective problem-solving in CS given appropriate support.

VI. Conclusions

The participants increased significantly in their self-efficacy in teaching ECS from participating in the professional development course. These results suggest that the professional development programs that provide mastery experiences and vicarious experiences for teachers can promote teachers' self-efficacy in the content knowledge and pedagogical knowledge of teaching CS. The findings also suggest the necessity to develop content-specific measures to gauge teachers' self-efficacy.

The findings on teachers' understanding of the equity issues in CS education suggest that teachers were able to see their roles as the agents of change and the students' participatory roles in the context of the societal system. In addition, the teachers' reflection on the mutual influences between the society and the agents within the societal system suggests the need to help them develop effective strategies that mediate the societal influences on the students' participation in CS education and on their equitable teaching practices.

References

[1] A. Yadav, C. Mayfield, N. Zhou, S. Hambrusch, and J. T. Korb, "Computational Thinking in Elementary and Secondary Teacher Education," *ACM Transactions on Computing Education*, vol. 14, no. 1, pp. 1–16, 3 2014.

[2] J. Goode, G. Chapman, and J. Margolis, "Beyond curriculum: the exploring computer science program," *ACM Inroads*, vol. 3, no. 2, p. 47, 2012.

[3] J. Goode, J. Margolis, and G. Chapman, "Curriculum is Not Enough: The Educational Theory and Research Foundation of the Exploring Computer Science Professional Development Model," *Proc. of the 45th Annual ACM SIGCSE Conference*, pp. 493–498, 2014.

[4] W. Aspray, "Recent Efforts to Broaden Formal Computer Science Education at the K-12 Level," in *Participation in Computing*. Springer, Cham, 2016, pp. 103–145.

[5] M. Tschannen-Moran and A. W. Hoy, "The differential antecedents of self-efficacy beliefs of novice and experienced teachers," *Teaching and Teacher Education*, vol. 23, no. 6, pp. 944–956, 2007.

[6] a. Bandura, C. Barbaranelli, G. V. Caprara, and C. Pastorelli, "Self-efficacy beliefs as shapers of children's aspirations and career trajectories." *Child development*, vol. 72, no. 1, pp. 187–206, 2001.

[7] J. A. Ross, "Teacher efficacy and the effects of coaching on student achievement," *Canadian Journal of Education*, vol. 17, no. 1977, pp. 51–65, 1992.

[8] R. M. Klassen, V. M. C. Tze, S. M. Betts, and K. A. Gordon, "Teacher Efficacy Research 1998-2009: Signs of Progress or Unfulfilled Promise?" *Educational Psychology Review*, vol. 23, no. 1, pp. 21–43, 2011.

[9] R. K. Henson, "From Adolescent Angst to Adulthood: Substantive Implications and Measurement Dilemmas in the Development of Teacher Efficacy Research," *Educational Psychologist*, vol. 37, no. 3, pp. 137–15, 2002.

[10] E. M. Skaalvik and S. Skaalvik, "Dimensions of teacher self-efficacy and relations with strain factors, perceived collective teacher efficacy, and teacher burnout." *Journal of Educational Psychology*, vol. 99, no. 3, pp. 611–625, 2007.

[11] A. Bandura, "Guide for constructing self-efficacy scales," in *Self-efficacy beliefs of adolescents*, 2006, pp. 307–337.

[12] L. Shulman, "Those who understand: Knowledge growth in teaching," *Educational Researcher*, 1986.

[13] R. Marks, "Pedagogical Content Knowledge: From a Mathematical Case to a Modified Conception," *Journal of Teacher Education*, vol. 41, no. 3, pp. 3–11, 5 1990.

[14] J. V. Driel and A. Berry, "Teacher professional development focusing on pedagogical content knowledge," *Educational Researcher*, 2012.

[15] C. Khourey-Bowers and D. G. Simonis, "Longitudinal Study of Middle Grades Chemistry Professional Development: Enhancement of Personal Science Teaching Self-Efficacy and Outcome Expectancy," *Journal of Science Teacher Education*, vol. 15, no. 3, pp. 175–195, 8 2004.

[16] O. Lee and C. A. Buxton, *Diversity and equity in science education : research, policy, and practice*. Teachers College Press, 2010.

[17] J. Margolis, R. Estrella, J. Goode, J. Holme, and K. Nao, "Stuck in the Shallow End:Education, Race, and Computing," pp. 71–95, 2008.

[18] S. Grover and R. Pea, "Computational Thinking in K-12: A Review of the State of the Field," *Educational Researcher*, vol. 42, no. 1, pp. 38–43, 1 2013.

[19] J. Goode, "Increasing diversity in k-12 computer science," in *ACM SIGCSE Bulletin*, vol. 40, no. 1. New York, New York, USA: ACM Press, 2008, p. 362.

[20] U. Fuller, C. Riedesel, E. Thompson, C. G. Johnson, T. Ahoniemi, D. Cukierman, I. Hernán-Losada, J. Jackova, E. Lahtinen, T. L. Lewis, and D. M. Thompson, "Developing a computer science-specific learning taxonomy," *ACM SIGCSE Bulletin*, vol. 39, no. 4, p. 152, 2007.

[21] J. J. Ryoo, J. Margolis, C. H. Lee, C. D. Sandoval, and J. Goode, "Democratizing computer science knowledge: Transforming the face of computer science through public high school education," *Learning, Media and Technology*, vol. 38, no. 2, pp. 161–181, 2013.

[22] N. Shah, C. M. Lewis, R. Caires, N. Khan, A. Qureshi, D. Ehsanipour, and N. Gupta, "Building equitable computer science classrooms," *Proceeding of the 44th ACM technical symposium on Computer science education - SIGCSE '13*, no. 1, p. 263, 2013.

[23] R. E. Bleicher, "Revisiting the STEBI-B: Measuring self-efficacy in preservice elementary teachers," *School Science and Mathematics*, vol. 104, no. 8, pp. 383–391, 2004.

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

[25] G. S. Howard, "Response-Shift Bias: A Problem in Evaluating Interventions with Pre/Post Self-Reports," *Evaluation Review*, vol. 4, no. 1, pp. 93–106, 1980.

[26] K. Krippendorff, *Content Analysis: An Introduction to Its Methodology*, 2004, vol. 79.

[27] W. J. Potter and D. LevineDonnerstein, "Rethinking validity and reliability in content analysis," *Journal of Applied Communication Research*, vol. 27, no. 3, pp. 258–284, 1999.

[28] H. F. Hsieh and S. E. Shannon, "Three Approaches to Qualitative Content Analysis," *Qualitative Health Research*, vol. 15, no. 9, pp. 1277–1288, 2005.

[29] J. Margolis, J. Goode, G. Chapman, and J. Ryoo, "That classroom'magic'," *Communications of the ACM*, 2014.