Online Professional Development for High School Computer Science Teachers: Features that Support an Equity-Based Professional Learning Community

Joanna Goode, Kirsten Peterson, Joyce Malyn-Smith, and Gail Chapman

Abstract— A grand challenge of the computer science (CS) for all education movement is the preparation of thousands of teachers with high-quality, accessible professional development (PD) that has evidence of improving teacher knowledge and pedagogical practices necessary to support the learning needs of diverse groups of students. While regional PD programs can provide in-person learning opportunities, geographic and time constraints often inhibit participation. This paper shares findings from an online PD program modified from the existing in-person Exploring Computer Science (ECS) PD program to provide teachers a facilitated online learning community model to support their first year teaching the course. The findings from this study have implications for future directions in the CS education field, indicating that this model of online PD, heavily based on shared experience among participants, can increase CS teachers' confidence in adapting and delivering lessons designed to be engaging and accessible to all students.

Index Terms—Collaborative learning tools, Computer science education, Distance learning, User generated learning content

1 Introduction

As computer science (CS) education sweeps the nation, it is evident that one of the grand challenges in broadening participation in computing is the preparation of well-prepared teachers whose pedagogical skills foster inclusive and engaging learning, informed by equitable practices. Research shows that professional development (PD) programs which lead to shifts in belief systems and pedagogies take place regularly over a sustained period of time, suggesting that teachers should have consistent PD encounters before and throughout the academic year [1]. However, given the low density of other CS teachers across schools, many teachers, especially rural teachers, are unable to attend workshops during the school year due to their home geography, travel limitations, costs, family responsibilities, and other barriers. Leveraging the power and flexibility of online learning holds potential to address this teacher preparation need.

In this paper, we report how a facilitated learning community model enables teachers to maximize their learning potential, take on an instructional orientation towards inquiry-based pedagogy, and address classroom barriers to broadening participation in CS education. The findings from this paper provide important evidence of how key design features of an online learning experience can support teacher learning while they simultaneously teach an introductory course rooted in principles of equity and inclusion.

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2 Literature Review

Our research examines how a professional learning community orientation towards broadening participation in computing can create a learning atmosphere for teachers that strengthens their confidence and knowledge in inquiry-based pedagogy in CS that is inclusive for all students, particularly historically underrepresented students in CS.

2.1 Professional Learning Communities

The concept of Professional Learning Communities (PLCs) involves engaging educators in reflective doing and problem solving that requires groups to "dig deeply into learning", ultimately seeking to enlarge educators' world views [2]. The design of the PLC, in this case, the facilitated online learning community PD, aligns with the findings of Teachers Know Best: Teachers' Views on Professional Development - quality professional learning combines the use of self-guided online resources and teachers' desire to collaborate on "planning, designing, and delivering instruction" [3]. The design of the PLC affords teachers both the environment and carefully scaffolded process for a shared learning experience with a focused orientation on supporting the development of pedagogy that broadens participation in computing; this specific pedagogical approach requires a central focus on how curriculum and instruction can serve to create either opportunities or

obstacles for African American, Latinx, Native Americans, and other girls to access culturally responsive classroom learning experiences [4]. In this study, we probed how a conceptual idea of PLCs could extend onto online spaces to support large-scale teacher preparation for teaching CS.

2.2 Online Learning for CS Teachers

Over the past two decades, research has highlighted the potential of online learning – in particular, online discussions – to foster and strengthen participants' higher order thinking skills ; however, it's not the fact that the discussion is "online" that leads to higher order thinking. Instructional design is key in developing effective online dialogue. Designing an online learning community that engages learners in the shared experience of learning content and engaging in meaningful dialogue requires design of a "meaningful context" where learners "practice higher order thinking skills purposely" [5].

In his work on online learning, Garrison [6] suggests that supporting the social dimension of learning requires establishing a "climate of trust and belonging that will support interaction and a questioning predisposition". Establishing a cognitive presence allows groups of learners to construct meaning through sustained communication, using reflecting and dialogue to support systematic inquiry [8]. Even though these "presences" are often examined separately, designing an effective Facilitated Learning Community grounded in shared experience requires participants to be engaged cognitively around the content, and socially around the interpersonal connections with colleagues. The *integration* of cognitive and social presence - this felt attunement among the community creates connection and meaning; ultimately, this is the heart of what we call "shared experience." Designing and Facilitating for social and cognitive presence is not trivial. It requires time, attention to learner needs, reflection, and thoughtful guidance to promote dialogue among learners.

Additionally, we know that STEM discipline areas require distinct learning experiences for teacher growth. In their study, Qian and colleagues [8] use design-based research to make three concrete recommendations for designing online PD specifically for CS teachers: match PD to teachers' background, align PD with the course curriculum, and use effective motivational design to enhance teacher engagement. These recommendations set the stage for examining more deeply the types of conditions that need to be attended to through instructional design when developing a facilitated learning community informed by equitable practices.

3 Methods

3.1 Setting of Study

This study took place in an online PD setting aimed at providing an alternative teacher learning experience to the typical four in-person quarterly PD days that are part of regional Exploring Computer Science (ECS) programs. For 10 years, standard ECS PD has taken place in three stages: 1) an in-person summer institute (5 days), 2) four 6-hour in-person PD workshops during the academic year, and 3) ongoing support, including a second in-person institute (5 days) the following summer. This study was designed to extend the field's knowledge on effective practices for supporting geographically diverse teachers through online PD as they embark on teaching a new, equity-focused CS course.

Given that the online PD detailed in this study was designed to replace well-developed face-to-face ECS PD sessions, central principles of ECS professional learning guided the design of the online learning experience. The key features of ECS PD include inquiry-based instruction, developing teachers' conceptual knowledge, and an equity focus on curriculum and pedagogy [9]. Building a robust community of practice with other teachers has been a central pillar to ECS PD [10]. These guiding principles, coupled with the implementation of effective practices for online learning as identified in the literature, shaped the initial development of the course.

3.2 Research Questions

Our research addresses questions related to two major components of the online experience: 1) Effectiveness of online features: *Which features of the online PD workshops are conducive to professional learning and perceived by teachers to be the most useful for their classroom teaching?* 2) Professional learning community: *How do teachers and facilitators build and sustain a learning community in an online PD environment?*

3.3 Research Participants

This study includes data from three cohorts of teachers, each participating in quarterly online PD sessions during the academic school year following participating as a cohort in a summer face-to-face PD workshop. The teachers involved in this study had participated in a week-long "all-comers" PD that involved participants from across the United States [11]. Since attending regional ECS PD quarterly workshops was infeasible for almost all of these teachers, we invited teachers from this national cohort to participate in the online ECS PD experience and in the accompanying research study. In Year One, 75 teachers participated in the online PD sessions. In Year Two, the instructional design of the course learning environment was refined based on Year One data and a second cohort of 77 teachers participated. In year three, feedback from participants and teachers informed course content and learning environment modifications, and an additional 55 teachers participated. Participants in the PD across all three years represented 34 states and Washington, D.C. Further, we included 8 online ECS facilitators in our research to triangulate our data and include their insider insights into online PD.

3.4 Data Collection and Analysis

Over three years we collected data that informed updates to the design, functionality, and facilitation of the online PD. To gather data, we logged qualitative participation comments, quantitative engagement analytics, and we designed surveys for teachers to complete before and after their online learning. The surveys probed teachers' satisfaction with features of online PD and their perceived

growth in understanding related to inquiry, equity, and the CS topic of focus. Further, the group of 8 online facilitators were part of an in-person focus group to discuss their experiences and reflections on the benefits and challenges of facilitating in an online environment.

To analyze the data, we were guided by professional learning community and culturally responsive computing theories to code patterns of participation across activities, including both qualitative and descriptive quantitative measures of engagement. Using a grounded theory approach, this study examined patterns of online participation and teacher discourse in online discussions. Through constant comparison and an open coding approach, we examined, compared, and conceptualized the data into illustrative themes. Code counts and frequency tables of codes across these themes ultimately allowed for key findings to surface around teachers' experiences with the design and learning community online. Further, this research design process was iterative, as frequent researcher and designer engagement with PD survey data and online participation patterns informed a series of design revisions over two design iterations and academic years, allowing for a systematicand data-informed process of course development and refinement.

4 Findings

The findings discussed in this section represent the most significant and informative design features and subsequent teacher growth in an online PD environment. In our quest to identify key design elements to support professional learning, our analysis focuses on how teachers described their learning and engaged in activities that cultivated the most generative participation.

4.1 Designing the Online PD Environment

Given that the online PD detailed in this study was designed to replace well-developed face-to-face ECS PD sessions, central principles of ECS professional learning guided the design of the online learning experience. The key features of ECS PD include [8]:

1. Immersion into inquiry and equity-based prac tices.
2. A focus on teachers' instructional practice.
3. Development of an on-going professional learning community of practice.

Further, we integrated the principles of developing deep and meaningful social and cognitive presence based on the key principles of the facilitated community learning model. Attending to both the social and cognitive issues online is particularly important because the absence of in- person cues, such as body language, requires alternative methods to judge the immediacy of understanding people and how individuals might be experiencing the learning environment. In addition to social and cognitive presence, the Facilitated Learning Community Model depends specifically on the key concepts of (1) experiencing the content with colleagues as a learner before teaching it, and (2) the guidance of a skilled ECS facilitator who has completed the ECS Facilitatator Development process as well as online facilitator training.

Fig. 1 illustrates how the online workshop content is organized and the types of learning participants experience within each section.

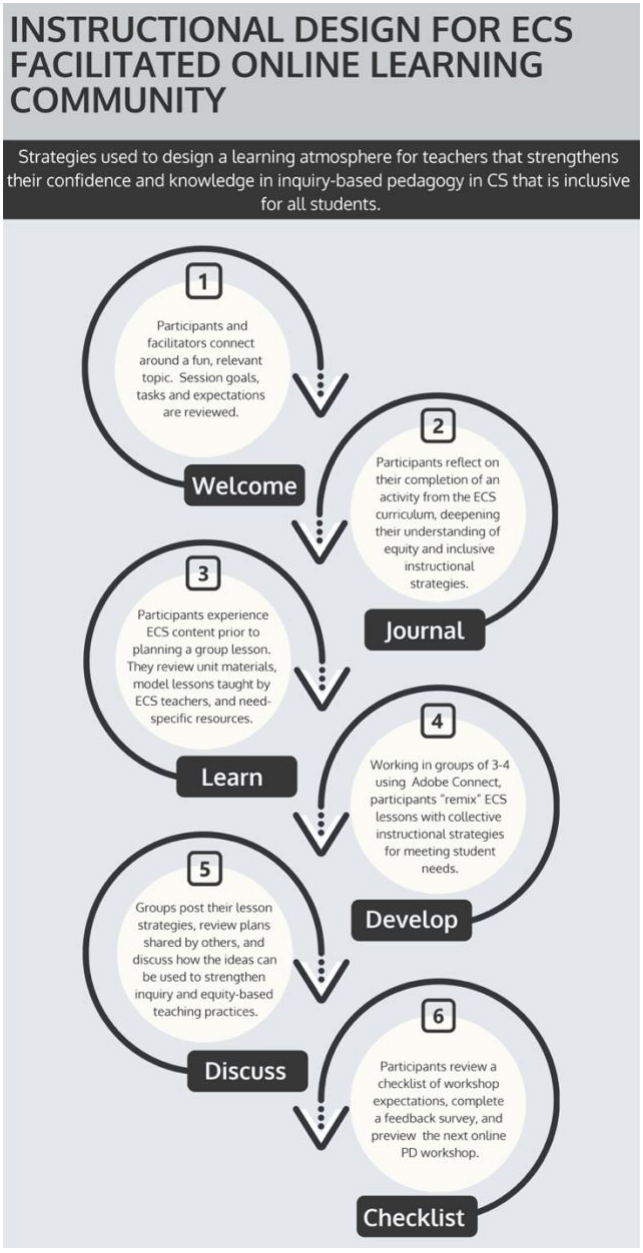

Fig. 1. ECS online PD session content progression.

4.2 Lesson Plan Remixing

Overwhelmingly, the feature of the online PD that emerged as an anchoring experience for teacher learning was a shared lesson-planning experience in which small groups all "remixed" the same existing ECS lesson to adapt in a way that would meet the needs of classroom students. The term "remixing" is used to describe the collaborative activity of taking an existing lesson from the ECS curriculum, and collectively working together to blend implementation strategies that have worked for different teachers in

different contexts. After small groups met online to discuss and blend ideas and strategies for their assigned lesson, they shared their resulting plans in a central forum so other teachers could browse and discuss the remixed lesson plans. Teachers reported great value in the collaborative and open experience, as one teacher noted on their post-PD survey, "It is really nice to collaborate and share ideas, information, and experiences. The obstacles and challenges of teaching a new course are definitely minimized with this ECS Community. I have found that many of us approach the lessons in a similar manner, but each of us have our own little spin depending on who we are, who our students are, and what areas we feel we need to emphasize."

The analysis of this data also suggested that the structure of the lesson plan remixing provided support for teacher learning in ways that furthered their agency in engaging in lesson plan modifications to meet the needs of their students in future lessons. "One can see that people were able to come up with some innovative ideas based on the structure offered by the course. I think that using lesson ideas by others is great. There is always going to be a need to tinker with a lesson from one class to another, but having a template really helps. I think with more structure to work with, there is more confidence in trying new things as well…" This structure of co-planning the same lesson, with individual flair, increased the confidence of these educators to take on an identity as innovators and imagine a variety of instructional methods and strategies that foster inclusive pedagogy.

Fig. 2 illustrates how the Discuss section of the PD is presented, encouraging dialog and debrief around lesson plan remixing.

Fig. 2. ECS online PD Discuss Section structure.

The importance of this lesson planning process, an authentic activity that CS teachers often do in isolation, was evident from the teacher comments and extensive engagement in the lesson plan activities. A critical part of the activity structure, and overall scaffolded learning experience is the supportive presence of trained ECS online PD facilitators. The facilitators are always present, observing group dynamics and nimbly guiding discussion as needed to encourage equitable participation and to draw out key instructional strategies that participants may be touching on but through follow-up questioning, could lead to deeper or more meaningful dialogue and sharing. As one facilitator noted, "in a lot of ways its really awesome because you get to look at well-formulated lessons." Quantitative evidence suggests also that teachers valued this anchoring activity, noting that their self-reported growth of content knowledge, inquiry-based pedagogy, and understandings of how to increase equity and inclusion were enhanced during this time.

Throughout this experience, we found that teachers responded positively to the crucial role of facilitators in keeping the pace of the teacher learning, offering social and cognitive supports, and answering questions, or in some cases, asking questions, to support teacher learning. The regularity and consistency of facilitation proved to be the most essential ingredient in the community-based model of professional development.

4.3 High-Touch Facilitation

The facilitation in this model embraced a high-touch, low facilitator-teacher ratio to ensure a welcoming and effectively facilitated environment. Typically, each facilitator worked with fewer than 20 teachers. Facilitators noted that this means that they were able to form individual relationships with teachers online, and also, that they were expected, and often able, to personally follow-up with participants who might have missed an assignment or an entire quarterly session. This persistence on the behalf of the facilitators undoubtedly boosted retention and led to teachers' measurable growth across quarters. This high-touch model also allowed facilitators to be attuned to the emerging needs of teachers, which then both informed the iterative PD development as well as the facilitators' approach to leading PD.

As these facilitators have historically also led quarterly in-person ECS workshops, they are particularly well-situated to collectively reflect on unique the opportunities and challenges of leading PD online. The facilitators noted that overall, they found that the online setting allowed teachers to learn more deeply, as they can go at their own pace throughout the asynchronous parts of the online PD. Facilitators believed that this format provides for more think time, and is better suited for some, but not all, personalities than the more fast-paced, face-to-face PD. One facilitator noted that while the reasons for the online PD offering were initially because of logistics to accommodate the quarterly PD needs for a national group of teachers, that the online setting "maximize[s] what style of learning works for teachers."

Another facilitator suggested that the online environment "encouraged equity amongst each other" while also noting that people do more online because of the availability of model lessons online. She believed that teachers providing common resources for one another had the effect of more substantive participation and discussions amongst the group of teachers.

The role of facilitators in online PD differed from in-

person PD settings in terms of communication between participants and the facilitator. Facilitators noted that because they are often not giving feedback orally, especially during online asynchronous discussions and activities, that they spend a significant amount of time providing encouraging and probing comments. In the group discussion, one facilitator explained how "you have to ask a whole lot more questions… online you don't have the conversation; you have to ask more probing questions." Because the time span for each quarterly PD is spread across 2 weeks online instead of 6 hours face-to-face, this lack of dedicated time can also be overwhelming for facilitators, most of whom are full-time high school teachers themselves. Yet, facilitators agreed that teachers are more apt to share their ideas and modify their lessons when they receive timely and customized feedback

4.4 Embedded and National Model of PD

The findings of this study also suggest that the design of this PD model, which focused on online quarterly support while being bookended with face-to-face summer PD sessions, was a particularly effective in building a community of learners. This embedded model, led teachers to remark on their excitement to re-connect with teachers that they had first met during the national week-long ECS PD the previous summer. For instance, teachers often talked about how they "picked up where they left off" with each other, and said, "Great opportunity to connect with peers from this summer and continue to learn from others", and "The group I was in was creative and focused. It felt like we were back in Golden. Awesome experience!"

Further, teachers suggested that the national distribution of teachers participating in the online PD brought additional depth to their own learning. One participant said "One very unique part about this course is the PDs and the ECS for all teachers' forums create a national community for this subject. It is very exciting to be able to discuss the curriculum with teachers from all around the country. It's like a huge professional learning community (PLC)." Another teacher echoed this sentiment, saying, "I find it so refreshing to share ideas with people from different parts of the country. I am always impressed how even with our differences all we have in common."

A particularly interesting dimension of this national online community was that some educators noted how online PDs provided learning experiences that could not be accessed in their local, in-person learning community. One teacher, who also benefited from a fellow CS teacher at the same school, spoke to the usefulness of working with a geographically diverse set of teachers: "I am lucky to have another teacher at my school taking part in this professional development at the same time. It allows us to collaborate on strategies and then debrief and make changes after we complete a unit. Even still, the process of creating a lesson plan with a long-distance group is different and very helpful. Working with teachers who have different experiences, populations of students, instructional requirements and time constraints gives a new perspective on what we are doing. I find that both helpful and inspiring."

In fact, having a group of teachers from diverse communities across the nation helped teachers imagine new ways of integrating equity-based lessons and pedagogy in the classroom. One teacher pointed out how one group's lesson provided a tangible example of culturally responsive teaching, "This comparison made me think of what it looks like to be a culturally responsive teacher and I think this open-ended task of creating a dialogue coupled with the structure that scaffolds the task, does a great job of allowing students to see that their own lived experiences and backgrounds are a vital part of the classroom and are embraced in activities such as this one." The power of this instance is not that the teacher observed features of culturally responsive teaching in one lesson, but extended the importance for the general CS classroom climate.

The findings from the study presented above provide compelling evidence around how teachers value the professional learning community that supports their learning in content, pedagogy, and notions of equity. The national cohort model seems particularly important for ensuring teachers had access to a set of diverse experiences, contexts, and students when engaging in a professional learning community in CS.

5 Discussion

This study offers preliminary evidence that carefully designed online learning environments can engage computer science teachers in learning that supports equity-based classroom instruction. We found that organizing teachers to work collaboratively, and at times synchronously, in authentic practices broke down the isolation that many computer science teachers feel and connected educators across cities and states. This national learning dynamic elevated peer-teacher learning, particularly in sharing novel strategies for pedagogy that is engaging and inclusive for all learners.

A surprising result of this study was the excitement teachers expressed for being part of a national learning community of teachers, even when more local teachers might be available for collaboration. For teachers, there are often few opportunities to engage in PD that allows them to learn from professional colleagues who represent vastly different geographies, school types, and life experiences. In this context, the online PD provided access to different perspectives and approaches that teachers noted were not necessarily accessible in local settings - which often propelled their own learning.

It is important to underscore that this online PD followed a face-to-face experience for these three cohorts of teachers. The social presence created throughout the workshops had already been sparked through initial face-to-face PDs and was regularly noted to be highly valued by this community of teacher learners. Unsolicited, teachers claimed that their successful experiences online were in part because of these prior relationships that had already established trust. Once online, teachers and facilitators were able to "pick up" and update one another on their months between the PDs. But beyond this initial

experience, the public nature of first developing, then sharing, and sometimes also reading others' lesson plans publicly further instilled the culture of trust, respect, and sharing. Again, this public sharing was made possible because of the online learning environment.

Further, the cognitive presence of the PD was enhanced through the facilitators engaging teachers in a cooperative lesson planning process that required a shared synchronous experience in addition to individual journaling and reflection. This process ensured that participants were engaged and supported in small groups that required extensive communication over the course of several days. The link between this PD activity and the actual lesson planning practices of individual teachers created an authentic context and purpose for this framework for teacher learning.

Still, we also continue to examine teachers' perceived needs of more content knowledge. As Deborah Ball suggests [12], subject-area teachers require specialized content knowledge - the knowledge of the content needed to effectively teach a course within a domain. We are responding to this data this upcoming year by tapping the knowledge of several teacher leaders who have completed their own online PD learning experience, but wish to stay involved by cultivating appropriate content for ECS teachers. This carefully curated set of resources, searchable by participants according to content level and keywords, will be merged into the ECS online PD as a central feature next year.

While this study provides useful information on how to build and facilitate online learning for national cohorts of computer science teachers, the findings also confirm that equity-focused learning for teachers, rooted in a foundation of inquiry-based pedagogy, can be nurtured and can grow in online contexts. Still, a major limitation of the research design of this study is the use of teachers' self-reported knowledge to measure their growth in the online learning environment. And while this study offers promising evidence of the effectiveness of the facilitated community-based learning model for computer science teachers, further studies that cut cross curriculum should further investigate and confirm these findings.

6 Implications and Conclusion

Scaling and broadening participation in computing requires a cadre of well-prepared teachers who have knowledge and efficacy in teaching CS to diverse groups of students. The research from this project on online PD for teachers contributes to the current knowledge base for effective design and facilitation practices for providing a robust, collaborative, and participatory PD experience for teachers fostered in an orientation towards inquiry, equity, and CS knowledge. Further, data gleaned from the research will directly inform translation of effective CS and equity-based pedagogical approaches that broaden participation into an online format which can serve as a model for other course developers seeking to create high quality inquiry-based, equity-focused, online learning options for CS teachers. The study also demonstrates how this blended model of online PD for teachers can leverage the power and flexibility of online learning not only for, but because of, geographically distributed teacher learners.

The CS Education field would benefit from building on the lessons learned from this project when designing and implementing PD on inclusion strategies to build capacity of CS educators teaching other CS courses to broaden participation in STEM. Efforts should be made to adapt the inclusion/equity pillars of the ECS course, both at the content and learning community environment levels, to other CS courses.

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