FIRST Principles to Design for Online, Synchronous High School CS Teacher Training and Curriculum Co-Design

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ABSTRACT

The Covid-19 pandemic has offered new challenges and opportunities for teaching and research. It has forced constraints on in-person gathering of researchers, teachers, and students, and conversely, has also opened doors to creative instructional design. This paper describes a novel approach to designing an online, synchronous teacher professional development (PD) and curriculum co-design experience. It shares our work in bringing together high school teachers and researchers in four US states. The teachers participated in a 3-week summer PD on ideas of Distributed Computing and how to teach this advanced topic to high school students using NetsBlox, an extension of the Snap*!* block-based programming environment.

The goal of the PD was to prepare teachers to engage in collaborative co-design of a 9-week curricular module for use in classrooms and schools. Between their own training and the co-design process, teachers co-taught a group of high school students enrolled in a remote summer internship at a university in North Carolina to pilot the learned units and leverage ideas from their teaching experience for subsequent curricular co-design. Formative and summative feedback from teachers suggest that this PD model was successful in meeting desired outcomes. Our generalizable **FIRST** principles—**F**lexibility, **I**nnovativeness, **R**esponsiveness (and **R**espect), **S**upports, and **T**eamwork (collaboration)—that helped make this unique PD successful, can help guide future CS teacher PD designs.

CCS CONCEPTS

• **Social and professional topics** → **Adult education**; **Computing education**.

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1 INTRODUCTION

Distributed and cloud computing, artificial intelligence and machine learning, cybersecurity, and the internet of things are some of the new frontiers of computing that are fundamentally transforming our lives. Initiatives like the "CS for All" movement in the US and around the world seek to address a recognized need for building a new generation equipped with the necessary computing skills to participate equitably in the new economy. There is a need, therefore, to also build on the foundation that current high school courses provide, to expand access for all students, to the most interesting and exciting frontiers of computing. The teacher professional development (PD) presented in this paper is in the context of a broader project, titled CSFrontiers (CSF). The goal of CSF is to build open-access curricular modules that introduce high school students, and especially females, who have completed AP CS Principles [4], to exciting CS topics–Distributed Computing (CSF:DC); Cybersecurity; Machine Learning; and Software Engineering. Our instructional design methodology and philosophy draw on principles of Understanding by Design [13] (working backwards from defined learning goals) and constructionist project-based learning to engage learners in deep and complex powerful ideas through simple and easy to use programming languages and abstractions. Our efforts employ iterative design-based research (DBR) [10] and involve teachers in co-design for curriculum planning, which is increasingly seen as a model for teacher PD [12].

1.1 Teacher PD and Curriculum Co-Design

This paper presents work with high school CS teachers on PD and co-design of the CSF:DC Module in summer 2020. CSF:DC uses NetsBlox, an open source, browser-based block programming environment [1] that extends Snap*!* to allow student programs to utilize internet data and services. It integrates distributed programming capabilities at a level accessible for novice programmers through two main abstractions – remote procedure calls (RPCs) and message passing. RPCs link Snap*!* code to online services and data sources such as Google Maps, Weather, NOAA climate change data, a movie database, Covid-19 data, and Twitter. RPCs enable students to create engaging and motivating projects grounded in real-world applications. NetsBlox message passing enables students to create real distributed programs like an online multiplayer game or chatroom, and to learn about computer networking.

The unique 3-week experience with teachers was planned to include training on DC basics in NetsBlox (week 1), facilitate a DC summer camp experience for high school students (week 2) and then use the experiences from the first two weeks to collaboratively

Table 1: CSF:DC PD phases and key activities

Week 1 (Teacher Training)	**a.** Intro to NetsBlox; **b.** Intro to Distributed Computing; **c.** Coding & training on RPCs and message passing broken down into a series of projects; **d.** Key pedagogies for CS teaching
Week 2 (Student Camp)	Teachers in groups of 2 or 3 work with students on a 1-week "camp" involving RPCs and message passing projects
Week 3 (Co-Design)	Teachers work in 2 groups to create/co-design 7 lesson plans for the CSF:DC Module

co-design refinements to the initial curricular materials to make them usable in the form of teacher lesson plans. The initial (pre-Covid) plan was for the first two weeks to be in-person followed by a final week of remote collaborative co-design. This meant that we needed a completely re-designed PD, summer camp, and co-design experience in light of Covid-19 where all planned activities were to occur in a distributed, remote fashion.

In addition to the unique elements of the teacher PD, we believe our approaches to redesigning the entire program for remote participation have significant lessons for the K-12 CS education community. The following section describes related work, although it should be noted that challenges imposed by the pandemic have been unique and not experienced nor studied. Section 3 describes our PD design. Section 4 describes our implementation, revisions, data gathered, and findings. In section 5, we discuss our FIRST principles–Flexibility, Innovativeness, Responsiveness (and Respect), Supports, and Teamwork–that guided this work and resulted in an overwhelmingly positive experience for us and the teacher cohort.

2 RELATED WORK

This work draws on our own prior research in teacher PD with high school CS teachers [6] as well as literature on online teacher preparation in CS education (e.g. [2, 7, 9]). However, given the uniqueness of the situation and not having experience or prior research in designing for 3 full weeks of synchronous engagement with teachers remotely in the time of pandemic-induced challenges such as lock-downs, we took inspiration from DBR. Although used in relatively few CS education efforts, DBR has been shown to be a popular methodology in the learning sciences for designing curricula, tools, and learning experiences. Designs are initially rooted in conjectures based on the context and learning theory, and then iteratively refined through piloting and examining how the assumptions play out in practice. DBR often views stakeholders as 'design partners' [3] and involves iterative design, that could even be in relatively short cycles [11]. Inputs and feedback are crucial to refine the program for current or future learners. Curriculum co-design and involving the teachers as 'design partners' in curriculum design is increasingly seen as a valued technique for unleashing the power of peer collaboration among teachers as well as professional learning. Research suggests that selecting co-design as a process serves as a form of professional development, especially for teachers who will be implementing the curriculum. It surfaces and addresses the tensions between practitioners' and researchers' views of teaching and learning, and thus results in innovations that are both theoretically and practically compelling [12]. Our intent in using co-design was thus aimed at addressing goals of teacher PD in a new topic in CS (distributed computing) and curriculum development that would leverage teachers' collective experiences and collaboration.

3 TEACHER PD PROGRAM DESIGN

The design of the teacher PD was guided by the question: How can we effectively replace an in-person summer program with a remote one? More specifically, (a) How can we make an online teacher PD experience engaging and productive for teachers? (b) How should we balance online and offline work and interactions? (c) How can we design for remote teacher collaboration for co-teaching and curriculum co-design?

Several design conjectures informed (initial) design of the PD.

- Limit pre-PD work to a few key tasks.
- The PD should largely be online and synchronous so that it would more closely replicate an in-person PD.
- Short real-time sessions to help prevent Zoom fatigue. Even though the PD was meant to replace in-person 8-hours a day sessions, we acknowledged that teachers had other Covid lockdown-related challenges to contend with.
- PD sessions would be a mix of live coding and CS pedagogy.
- Coding pedagogy included live-coding [8] to help explain DC concepts while creating projects, and Use-Modify-Create [5] to help teachers develop fluency with DC in NetsBlox.
- Flexibility in teacher collaboration decisions since in-person interaction affordances were missing.
- Use teacher inputs on off-Zoom work: Uncertainty around how much time teachers would have outside of the Zoom sessions meant that we could not plan ahead of time for specific tasks/homework for teachers.
- Need for online asynchronous supports for interactions.

3.1 Design elements in response to Covid-19

The 3-week summer PD was designed in 3 key phases each mapping to one week (see Table 1). For week 1, which was the most intense time of teacher training alongside the researchers, we planned (a) An introduction to the broader CSF project and research; (b) An introduction to DC and its key concepts; (c) A curricular sequence of NetsBlox projects to bring RPCs and message passing to life; (d) Sessions on pedagogy (growth mindset, pair programming, PBL, real-world connections, culturally relevant pedagogy, student identity and intersectionality). Table 2 shows a typical daily schedule.

Additionally, the following were key elements of the PD design, inspired by research and prior PD experiences [6].

- Pre-PD work was limited to creating a NetsBlox account, introductions on the Piazza class group, and playing a multiplayer game in NetsBlox involving message-passing.
- We framed the program as supportive and flexible. We felt it was important to let the teachers know at the very outset that we would be supportive of absences necessitated by unavoidable/unplanned events.

Table 2: A typical day during Week 1

12:00-1:00	Office hours (Drop-in)
12:45-1:00	Staff Logs Into Zoom
1:00-1:15	Survey Feedback/Updates
1:15-1:30	NetsBlox Activity Intro
1:30-1:45	NetsBlox Coding Activity
1:45-2:00	
2:00-2:15	
2:15-2:30	Break
2:30-2:45	NetsBlox Coding Activity
2:45-3:00	
3:00-3:15	Reflect & Debrief
3:15-3:30	Break
3:30-3:45	Pedagogy
3:45-4:00	Pedagogy
4:00-4:15	Reflect & Debrief
4:15-4:30	Daily Feedback Survey (Link)
4:30–5:00	Review feedback & tweak plan

- Fluidity in decisions of teacher group work so that we could involve teachers in those decisions.
- While the original program would have had teachers in-person for full days of training, we planned for only 3.5 hours of Zoom time (post-noon for all but the one researcher on Pacific Time) for teachers.
- An hour was added at the beginning of each day for "Office Hours" for additional help with the coding projects.
- Zoom recordings were made available to teachers so that they could re-visit them, if necessary.
- A Google folder for sharing various materials was created.
- A "class group" was created on Piazza for asynchronous interaction: sharing of ideas, planning, posting articles and videos, continuing conversations and sharing materials along with messages that could also be "pinned" (to the top) if they were time-sensitive or significant.
- Design for **short-cycle DBR iterations** based on daily formative feedback. Each day in week 1 and 2 ended with teachers using the last ½ hour to reflect, debrief, and respond to these survey questions: *What went well today? What could be improved as we move forward? What was one success you had today? Is there anything else you'd like to share?*
- The research team met at the end of each day to review survey feedback and plan for recommended changes.

4 SUMMER PROGRAM IMPLEMENTATION

This section describes the actual execution of the CSF:DC PD in June-July of 2020 at the height of the Covid-19 pandemic in the US.

4.1 Participants and Data Measures

5 Female and 2 male high school CS teachers from North Carolina (4), Tennessee (2), and Massachusetts (1) were invited to participate in the Summer program. The teachers represented a diverse racial mix– the 5 female teachers were African-American (2), White (2), and Indian-American (1), and both male teachers were White. The teachers were invited based on their prior experience working on high school CS PD teams and summer camps for high school students. All the teachers were teaching advanced placement high school CS courses (AP CS Principles or AP CS A), but they had little to no experience teaching Distributed Computing. Most of the teachers had familiarity with the Snap*!* Programming environment (of which NetsBlox is an extension). The teachers were paid a stipend for their participation. The following data measures were used to guide ongoing and future design refinements:

Daily formative surveys: As described in section 3.1.

Summative feedback sessions: We recorded the Zoom sessions devoted to gathering summative feedback at the end of each week. Session 1 was focused on the learning experience of DC projects in NetsBlox. At the end of week 2 we had sessions to a) plan Week 3 teacher collaboration and the co-design process and deliverables, and b) showcase student campers' final projects (to which members of the project advisory board were also invited). Session 3 was a reflection on the collaborative co-design they had just completed. However, given that it was the last day of the program, some teachers also commented on the overall experience.

Summative feedback survey: We administered a survey with mostly Likert scale items to get feedback on various elements of the overall PD and learning experience. In addition, we also asked teachers how likely they are to use the learning of DC with NetsBlox in their classes in the coming year and how they planned to use the materials. We also asked teachers a few open-ended questions about what they liked or what could be improved for the future.

4.2 Just-in-Time refinements in Week 1

Teachers' formative feedback was collectively reviewed daily by the research team immediately after the teachers completed the survey. We paid special attention to responses to "What could be improved as we move forward" and discussed what action we would take to address any issues. The first 15 minutes each morning (days 2-5) were dedicated to sharing their broad feedback (successes and suggestions). The following list outlines some of the key responses to this question that we addressed during Week 1.

Day 1 Feedback:*"slow down with the coding"; "Keeping up with time. We all are really zoomed out with our classes and other required meetings"* (We'd overshot the first day by 15-20 minutes). **Action**: Strictly adhered to time and schedule for remainder of PD.

Day 2 Feedback: *"Slowing down the NetsBlox presentations just a little."; "i think we can do some of the coding on our own prior to meeting that way we can ask more questions about where we have misunderstandings and present more ideas. i kind of like a flipped classroom." "A little clearer communication of what is expected of participants in terms of deliverables, "homework" etc."* **Action**: For days 3-5, we created live-coding-style videos and uploaded them for teachers to work with before live sessions. Some involved asking teachers to fix a bug (these were discussed the next day). We also gave them "optional but recommended" homework to extend the code or think of other projects and applications and share on Piazza.

Day 3 Feedback: *"I saw the schedule is 3 weeks. Is there a vision for what weeks 2 and 3 look like yet? Do both weeks include synchronous time? We're planning some things and I want to know how to schedule my time." "What are the expectations for next week when working with students?"* **Action**: We tweaked the agenda to devote

(more) time on Days 4 & 5 for addressing the co-teaching of students in week 2 by forming teacher groups, and planning—together with the teachers—a detailed agenda for week 2.

Day 4 & 5 Feedback: *"I am not sure - loved everything today. I think it's good at this point.; "keep doing what we are doing- Planning together and sharing ideas" "Love Netsblox. I think students will also"; "I think we're good. The challenge is exciting. Looking forward to blazing some trails."* **Action**: None!

4.3 Teacher collaboration in weeks 2 & 3

Teacher collaboration to co-teach the summer camp students (divided into 3 groups of 8-10 students) in week 2 and then co-design the lesson plans in week 3 based on experiences in weeks 1 & 2 were the hallmarks of the PD. At the end of week 1 we asked teachers to divide into groups of 2 or 3 teachers. Teacher groups represented diversity in terms of gender and state. Teachers devised their own timetables and plans to work with each other every morning. The schedule (similar to week 1) involved afternoon work with students. We made Zoom rooms available for teacher use, if needed. We set up a 1-hour pre-camp time on Zoom for the teacher and researcher groups to meet to discuss teachers' plans and help with any concerns or questions. Teachers filled out the formative feedback survey at the end of each day, and researchers met at the end of each day to go over the feedback (as in week 1).

Teachers and researchers met on day 4 of week 2 to discuss a detailed plan for co-design in week 3. Each teacher was tasked with creating one lesson plan serving a DC project and idea. Teachers were asked to plan how they would best like to collaborate. Teachers felt there were ideas and materials created by each group in week 2 that they would all benefit from. They decided to collapse into 2 groups (of 3 and 4 each) ensuring that each group had a member from each of the week 2 groups. We provided them with templates and supports for the lesson plan deliverables.

4.4 Summative Feedback & Results

Based on the student projects in week 2 and co-designed lesson plans in week 3, we believe the summer program was a resounding success. Not only did the teachers learn from the experience as evidenced by both outcomes, they brought their teaching experience to make key value-additions to the lesson plans in terms of identifying a need to articulate prior knowledge and the spiral curriculum nature of the DC projects. Furthermore, they also incorporated ideas to round out the units with non-programming activities such as student research projects on understanding networking more generally. Such activities tied well to the pedagogical aspects of a project-based curriculum that connected ideas to the real world.

For teachers' summative feedback, we analyzed the Zoom session at the end of week 3 (focused mainly on the collaboration and co-design) and the summative feedback survey. One teacher could not attend the final Zoom session and another teacher did not complete the feedback survey. Given Covid-induced pressures in teachers' lives, we worked with data from 6 teachers in each case.

Teacher feedback on the summer experience was overwhelmingly positive. The following are mean scores on aspects of PD from the summative survey, and quotes from the final session and survey on the overall PD experience, collaboration, and CSF:DC course.

Table 3: Mean scores in summative survey (out of 5)

Field	Mean (SD)
I can use this training to positively impact the achievement of my students.	4.67 (0.47)
The content of the professional development is relevant to my professional responsibilities.	4.33 (0.75)
The facilitators helped me understand how to implement my learning.	4.67 (0.47)
This professional development will extend my knowledge, skills, and performances.	4.67 (0.47)
This professional development was tailored to meet my needs as a learner.	4.83 (0.37)
The agenda and plan were appropriate for the activities.	4.83 (0.37)
The agenda and plan were conducive to learning.	4.83 (0.37)
New practices were modeled and thoroughly explained.	4.67 (0.47)
Sufficient time was provided for guided practice and tasks.	4.50 (0.5)
The facilitators were knowledgeable and helpful.	5.0 (0.0)
The facilitators were well prepared.	5.0 (0.0)
The instructional techniques used facilitated my learning.	4.67 (0.47)
The materials used were accessible and enhanced my learning.	4.67 (0.47)
The PD activities were carefully planned and well organized.	4.83 (0.37)
The PD goals and objectives were clearly specified.	4.67 (0.47)
The PD included a variety of learning activities relevant to the topic.	4.67 (0.47)
Time was used efficiently and effectively.	4.67 (0.47)

Overall PD experience: T1:*"I thought it was a great experience and it was good to have the remote experience and see doing it 100% remote and making it work."* **T4:***"Given the current world situation, they (facilitators) could not have done anything more. I loved the experience. I got confidence that I can engage my students as well. The tools the instructors used and the agenda they set was very systematic and very conducive for higher order thinking. That is the best thing!"* **T5:***"The pace and the presenters made this pd delightful."* **T6:***"It was great training and I learned so much"* (What I liked best) *"The hands-on learning before we taught it to the students"*

Collaboration: On the survey, some teachers described the collaboration as what they liked best about the experience. **T1:***"We, we got together and then kind of said, Okay, you know what, we all are kind of loners and we do our own thing better. So we agreed on this sort of divide and conquer method."* (What I liked the best was) *"Collaborating with peers and learning from experts."* **T2:***"I think everybody has something to bring to the group, but I was like, man, your skill set with these PowerPoints. It saved my life.. For me that has always been like, it takes me so long way around. so like tidbits of something from everybody.* **T3:**(What I liked best) *"The ability to work with peers and share ideas and resources."* **T4:***"I really enjoyed this professional development. The facilitators were fantastic and really expanded my knowledge of computer science and its pedagogy. I learned a lot from everyone involved and feel comfortable and confident that I can incorporate what I learned into my classroom."* **T5:***"the grouping worked out in our favor, like beneficially for us and that we were allowed to have the group when we needed the group, but we were also allowed to work very independently of the group. So I think, I think everything went really well in our groups.*

The CSF:DC curriculum: T1:*"I'm excited about the possibility of offering an entire course as an option for students who have taken AP CSP and who want to learn more about CS, but do not want the*

hard-core programming course that is AP CSA." **T3:** *"My plan is to incorporate this into How Computers Work unit after the exam.* **T4:** *"I am excited to use the RPC's to my cyber security students, making them understand how different systems can interact with each other and why networking is an integral part of everything we do these days."* **T5:** *"The projects we worked on through the CSFrontiers: DC training are ideal for my class. With the virtual delivery of my course, allowing students to collaborate in real time on a project, and understand HOW the collaboration works is a great learning experience for my students."* **T7** *"I love how these activities start to show how you can create a program that interacts with the world both by pulling data to manipulate and by sending information to another user."*

5 "FIRST" PRINCIPLES FOR CS TEACHER PD

There are many key lessons and takeaways from our CSF:DC teacher PD experience that are relevant for Covid-constrained as well as normal times. Our experience and teacher's feedback demonstrate, once again, the value of using co-design as an effective conduit for professional learning. Adding a summer camp for teaching experience in between training and co-design was a unique element that truly benefited the teachers (and the campers). Teacher feedback underscored that the co-design benefits from the experience of working with learners, especially given the newness of the topic. We believe that it was the collaboration— co-teaching during the summer camp—that became a crucial building block for the effective co-design and collaboration that was to follow. The short-cycle iterations inspired by DBR helped us be responsive to teachers' needs, and make them feel respected and heard. In a sense, *the teachers helped contribute to design their own PD as well!.*

Based on our findings and analysis of the feedback, we have distilled the following **FIRST** principles or elements of a PD design framework that we believe were key to this engaging and productive PD experience for CS teachers.

Flexibility: As one teacher said, *"The flexibility of the facilitators and willingness of the group to pursue the best ideas meant all obstacles were overcome."* Foregrounding teachers' needs meant that we needed to be flexible—about time and timing, pacing, teacher availability and decisions to shape the agenda and teamwork, and how much teachers could engage and contribute in offline hours.

Innovativeness: We had to innovate every step of the way to make possible– through remote, synchronous interaction– everything that we had planned pre-Covid. One of the key innovations that proved to be very successful, especially given the newness of the concepts and tools being learned, was the decision to intersperse the teacher training and curriculum co-design with an opportunity to (co-)teach students (albeit in a "remote" summer camp mode).

Responsiveness (and **Respect**): Our DBR-inspired design meant that we could be responsive to feedback through the PD process. Short-cycle iterations helped with course-correction that were also indicative of our respect for teacher voices.

Supports: We felt that the asynchronous supports provided through Zoom office hours, the Piazza group, step-by-step live coding videos, Zoom recordings (as well as week 2 supports during the summer camp) were of paramount importance to making this teacher learning "excellent" all around. As one teacher put it, *"Everything is very well planned and organized. The instructors were very helpful, available any time I needed them, listened to our requests and helped us every step of the way. That does not mean there was coddling - but clear expectations were given, and they were right there to guide us through to achieve the goal."*

Teamwork: A big part of what teachers loved about the experience, especially in weeks 2-3, was the teamwork. Teacher collaboration in co-teaching the summer camp student groups and curriculum co-design became a linchpin of this PD experience. It was invaluable to the teachers and became one "the best aspects of the PD" for them. We believe that it was good teamwork on the part of the research team as well that helped make the entire experience an enjoyable one for the PD organizers too.

5.1 Scholarly implications & next steps

We believe that the **FIRST** principles are generative and applicable to any CS teacher PD. However, the small sample size is a limitation, and this outcome may not be generalizable across countries or with different target cohorts. More work needs to be done to replicate this model in other contexts. We believe this work marks a significant addition to the growing scholarly literature on K-12 CS teacher PD, and especially for designing online CS teacher PD. Our next steps involve replicating the CSF:DC PD process and principles in subsequent teacher PD and co-design for future CSF modules.

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